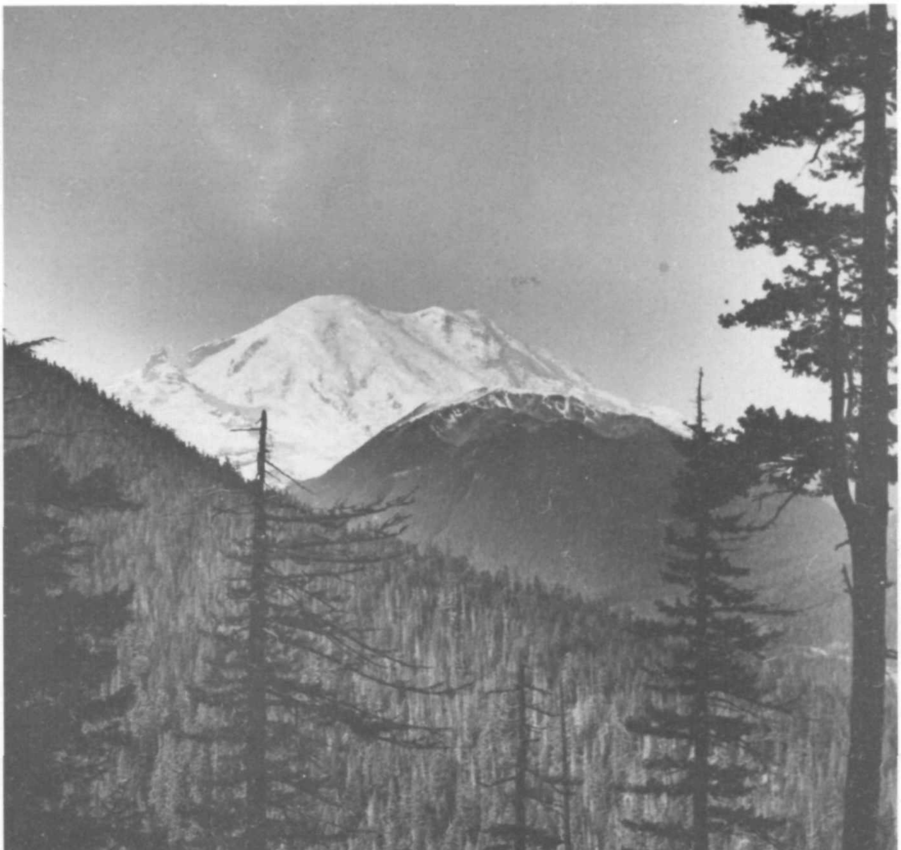
THE FOREST COMMUNITIES OF MOUNT RAINIER NATIONAL PARK



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Abbreviations of species used in names of habitat and community types

Abbreviation	Species	Common name
ABAM	*Abies amabilis*	Pacific silver fir
ABLA2	*Abies lasiocarpa*	Subalpine fir
ABPR	*Abies procera*	Noble fir
ACTR	*Achlys triphylla*	Deerfoot vanillaleaf
ALRU	*Alnus rubra*	Red alder
ARUV	*Arctostaphylos uva-ursi*	Kinnikinnick
BENE	*Berberis nervosa*	Oregongrape
CEVE	*Ceanothus velutinus*	Snowbrush ceanothus
CHNO	*Chamaecyparis nootkatensis*	Alaska-cedar
ERMO	*Erythronium montanum*	Avalanche fawnlily
GASH	*Gaultheria shallon*	Salal
HODI	*Holodiscus discolor*	Creambush oceanspray
LYAM	*Lysichitum americanum*	Skunkcabbage
MEFE	*Menziesia ferruginea*	Rustyleaf
OPHO	*Oplopanax horridum*	Devilsclub
POMU	*Polystichum munitum*	Swordfern
PSME	*Pseudotsuga menziesii*	Douglas-fir
RHAL	*Rhododendron albiflorum*	Cascades azalea
RULA	*Rubus lasiococcus*	Dwarf blackberry
RUSP	*Rubus spectabilis*	Salmonberry
TIUN	*Tiarella unifoliata*	Western coolwort
TSHE	*Tsuga heterophylla*	Western hemlock
TSME	*Tsuga mertensiana*	Mountain hemlock
VAAL	*Vaccinium alaskaense*	Alaska huckleberry
VAOV	*Vaccinium ovalifolium*	Ovalleaf huckleberry
VASI	*Valeriana sitchensis*	Sitka valerian
VISE	*Viola sempervirens*	Evergreen violet
XETE	*Xerophyllum tenax*	Common beargrass

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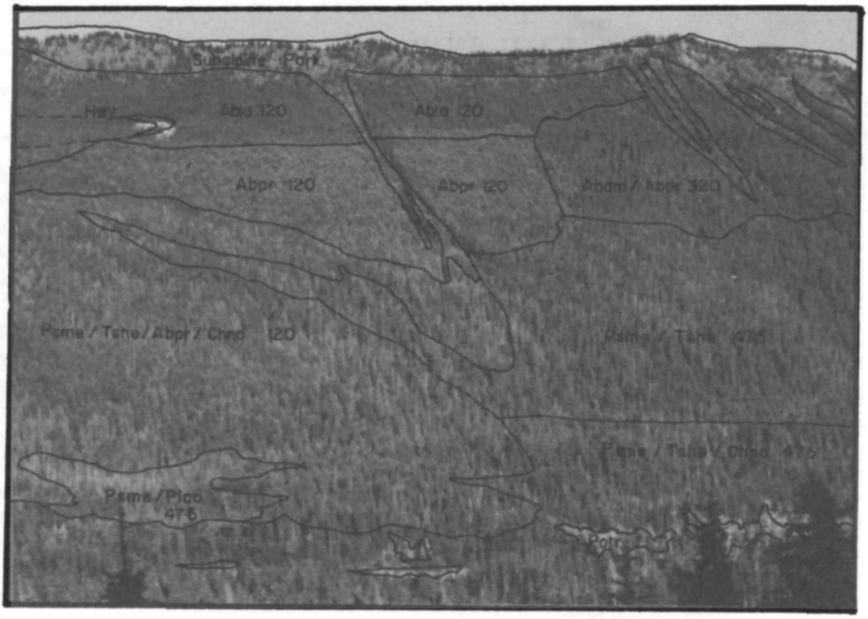

Frontispiece. Mosaic of forest stands of varying age and composition on Sunrise Ridge, Mount Rainier National Park.

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THE FOREST COMMUNITIES OF MOUNT RAINIER NATIONAL PARK

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As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering the wisest use of our land and water resources, protecting our fish and wildlife, preserving the environment and cultural value of our national parks and historical places, and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to assure that their development is in the best interests of all our people. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

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1987

Summary

The forests of Mount Rainier National Park are a major natural resource. They extend up the mountain slopes to an elevation of about 1800 m (5,800 ft) and occupy 60% of the Park landscape. This phytosociological study, conducted during 1975–80, has provided a detailed description and classification of these forests for the use of park managers and visitors. The forests lie within three zones based upon the major climax tree species: *Tsuga heterophylla, Abies amabilis*, and *Tsuga mertensiana*. A total of 14 plant associations and 5 community types were recognized across the range of environmental conditions represented within the Park. The moist forest types have rich understories that include numerous herbaceous species and shrubs such as *Oplopanax horridum*. The *Abies amabilis/Vaccinium alaskaense* Association is typical of modal environments and the most extensive formation within the Park. Dry associations are typified by *Gaultheria shallon*- and *Berberis nervosa*-dominated understories. High-elevation forest types belong to the cold grouping and are typified by herbaceous understories on better drained sites and by dense understories of ericaceous shrubs on wet sites. Forest types show strong relations with elevation and landform, although details vary in the four Park quadrants. Moisture, temperature, and duration of snowpack appear to be the primary environmental variables. Wildfire has been the major forest disturbance; approximately 90% of the forests have arisen after fire, 7% after avalanche, and 2% after lahars. The natural fire rotation was calculated as being 465 years before white settlement of the region. Climatic episodes appear to have been important in creating conditions for wildfire. Uses of the forest type classification by managers include interpretations of the potential value of sites for development, productivity and resilience, value for wildlife, and visitor interest. Large color-keyed maps (Plates 1 and 2) are included on the inside back cover to show the distribution of the plant associations and major forest age classes within the Park.

Chapter 1
Introduction

Dense, coniferous forests clothe the lower slopes and valleys of Mount Rainier National Park (the Park). They surround the lofty volcanic centerpiece and provide the locale for much of the visitors' activity. The forests are rich and varied—from massive, somber stands of *Pseudotsuga*, *Tsuga*, and *Thuja* in the valley bottoms to open groves of *Abies lasiocarpa* on high ridges. They are, in themselves, a major resource of the Park, providing outstanding examples of the virgin forests that once occupied the mountains and lowlands of western Washington.

The forest ecosystems of Mount Rainier have received little systematic study in contrast to the geological features and subalpine meadow regions. Yet sound management decisions, as well as accurate interpretive programs, require a basic knowledge of the sylvan landscapes. What kinds of forests are present and how are they distributed over the landscape? What role have disturbances, such as fire, played in their formation? In what direction and at what rate are successional changes taking place? What forest types do various birds and mammals use?

Our phytosociological analysis of the forest communities of Mount Rainier National Park was conducted from 1975 to 1980. The objectives of this study were to:

1. Develop a classification of the potential natural vegetation and forest habitat types (*sensu* Daubenmire 1966);
2. Describe the existing forest vegetation and place it in the context of the classification; and
3. Relate the forest communities to key environmental factors.

We present the results of our research in this monograph. Fourteen major plant associations, defined by mature forest stands, are identified along with five community types representing some distinctive early stages of forest succession. Each type is described and related to other types and to environmental conditions. Forest line is the upper bound-

ary of the study area; the forest patches and tree groups of the subalpine parklands are, therefore, not included in this monograph.

The research had several purposes. First, to provide park managers with an understanding of the forest patterns. Managers and interpreters are provided detailed information on the composition and structure of the forests, as well as a scheme that shows their relationships to each other and to the landscape. Many management interpretations are obvious and are presented in Chapter 8. Some habitats have exceptional importance for elk, for example. Second, to provide scientists with a framework of forest types for their studies of various organisms and processes, a system that allows results to be extrapolated from one locale to another. Last, but not least, to provide the visitor with a better appreciation of the diversity, value, and dynamic nature of these magnificent forests; this monograph is particularly useful in providing detailed background to the narrative "The Forests of Mount Rainier: A Natural History" (Moir 1986).

A map showing the distribution of habitat types over Mount Rainier National Park is included as a basic part of this report (Plate 1). This map is based on extensive ground surveys conducted during the development and testing of the classification. A map showing the distribution of forest age classes is also included (Plate 2). This map is based on an analysis of forest disturbances during the last 1,000 years; supportive information is provided in Chapter 7 and comprehensively reported by Hemstrom and Franklin (1982).

These forest descriptions and maps are only one step in a systematic study of the forests at Mount Rainier. Permanent sample plots have been established in most of the forest types for observation of long-term changes and are yielding valuable data on the dynamics of these forests (Chapter 7). Temperature regimes of several forest types have also been studied (Greene and Klopsch 1985). Studies of the vertebrate animals characteristic of the old-growth forests are underway. Hence, this monograph is only one indication of an expanding understanding of these forests, and we hope it will lead to their greater appreciation and improved management.

Chapter 2
Physical Setting

Mount Rainier National Park occupies 96,797 ha (241,922 acres) on the western slopes of the Cascade Range in Washington. The diversity of climate, geology, and soils found in this rugged mountain region is outlined in this chapter. Much variability in both vegetation and environment is related to the geography of the Park, making its division into four quadrats of major drainage basins (Carbon, Nisqually-Puyallup, Ohanapecosh-Cowlitz, and White) (Fig. 1) useful in much of the discussion that follows.

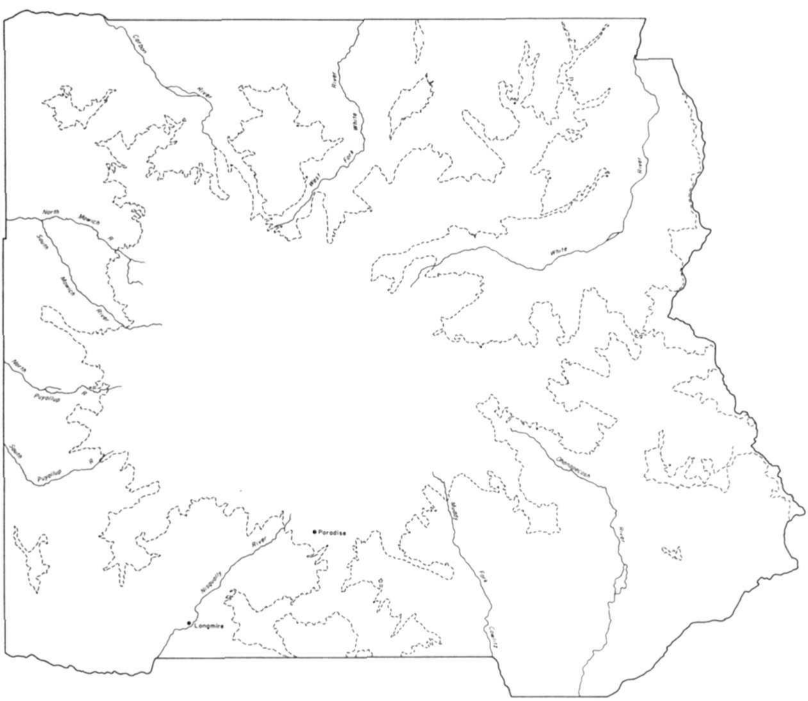


Figure 1. Outline of Mount Rainier National Park showing major features and subdrainages.

Climate

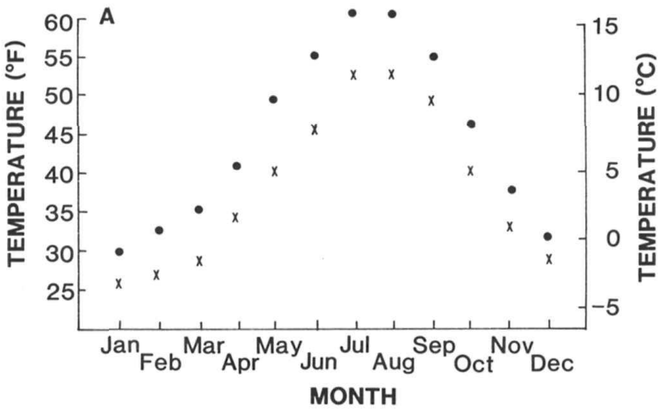
Mount Rainier is situated within a temperate, maritime climate. A high pressure region over the north Pacific Ocean shifts southward during fall and winter, and warm, moist air moves from a southwesterly direction into the Cascade Range. Condensation of this cooling air as it rises along the mountain slopes results in a rainy season during late fall and winter and continues almost without break until March or April (Phillips n.d.). At the higher elevations, snow begins accumulating in early November and builds to depths of 5–7 m (18–23 ft) or more by March or April. These wet seasons end when high pressure again develops over the region, and July and August are usually comparatively dry.

Seasonal trends of mean monthly precipitation and temperature are given in Figure 2. Several climatic zones exist within the forested region around the massive ice-laden volcano. The mean monthly temperatures are 2–4°C (4–9°F) lower at Paradise (parkland subzone of *Tsuga mertensiana* Zone) than at Longmire (*Tsuga heterophylla* Zone). In addition to the gradient in temperature with elevation, the precipitation varies both with elevation and with position around the volcanic cone. Greatest precipitation is recorded at the high-elevation Paradise station, often in the form of snowfall. Maximum snow accumulation occurred there in March 1956 when the depth reached 9.3 m (367 in). At lower elevations, the Parkway station in the White River drainage is in the driest sector and the Carbon River station is in the wettest sector (especially during spring and summer months).

Because of the dry summers at low to intermediate elevations and the forest vegetation's high transpiration rate, soil water supply is low by August and September; summer months can result in strong contrasts in soil water supply for various forest types (Zobel et al. 1976). At higher elevations, however, snow melt, runoff, and shorter growing seasons considerably lessen the duration and intensity of water stress in forest vegetation. Also, fog or cloud condensation at elevations below dewpoint further lower the gradient in transpiration during summer months. Therefore, forests within the climate of the *Tsuga mertensiana* Zone appear to be influenced and differentiated by topographic variations in snow accumulation and duration, soil water drainage, and heat budgets. Growing seasons are comparatively short, and opportunities for tree seedling germination and survival are limited by snow depths, low temperatures, and restricted periods of photosynthesis.

Geology

The geology of the Park has been clearly summarized by Crandell (1969). In the forested landscape, four general geological processes have influenced forest development: (1) Tertiary volcanism and sedi-



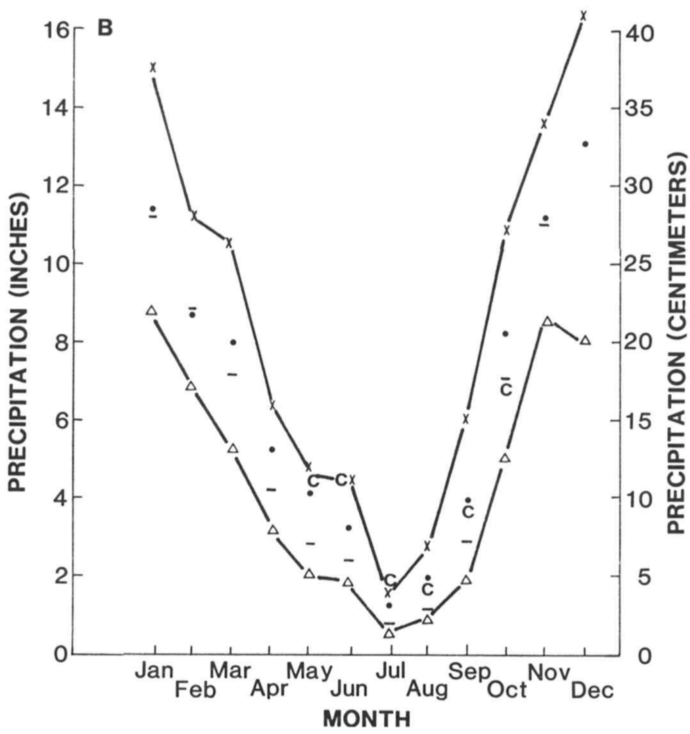


Figure 2. Temperature and precipitation regimes in Mount Rainier National Park: *A*, mean monthly temperatures from Paradise station (×) at 1665 m (5,550 ft) and Longmire station (•) at 829 m (2,762 ft); *B*, mean monthly precipitation from Paradise station (×, 31–39 years of record, 1665 m or 5,550 ft elevation), Longmire (•, 48–50 years of record, 829 m or 2,762 ft elevation), Ohanapecosh (–, 24–28 years of record, 577 m or 1,925 ft elevation), Carbon River (c, 21–22 years of record, 608 m or 2,026 ft elevation), and Parkway (Δ, 13–17 years of record, 945 m or 3,150 ft elevation). (Adapted from U.S. Department of Commerce, Weather Bureau, 1965.)

mentation; (2) Pleistocene and Holocene eruptions that produced the Rainier volcanic cone and showered the region with volcanic ash; (3) lahars, landslides, rockfalls, and other mass wasting and removal processes; and (4) glacial and fluvial events of the Pleistocene and Holocene eras.

Much of the forested landscape further away from the Rainier volcanic cone occurs on ridges of Tertiary rocks radiating from it in spokelike fashion. Major geologic formations include the Ohanapecosh (sandstone and breccias), Steven's Ridge (welded ash-flow tuffs), and Fifes Peak Formations (andesite). Granodiorites intruded the Mount Rainier area about 12 million years ago; they outcrop in various places along the White, Carbon, and Nisqually valleys, and include the Tatoosh Range. The distribution of these Tertiary formations is shown on a map by Fiske et al. (1963). Many of our study plots of steep colluvial slopes or ridges (such as Backbone Ridge) occur on these formations that predate the Rainier volcanic cone.

Mount Rainier is a complex composite volcano that probably originated half a million years ago. Ridgetops such as Rampart Ridge and Klapatche Ridge were formed by andesitic lava flows that moved down and filled old river valleys. Similar flows, piling on top of one another through time, built up the central cone until its summit was some thousands of feet higher than Mount Rainier is at present. During Holocene time (the past 10,000 years), eruptions from Mount Rainier and other volcanoes, particularly Mount St. Helens, have showered the area with a variety of pyroclastic deposits (Mullineaux 1974). These deposits are particularly important because they form part or all of the soil materials in most forested areas.

Many lahars (volcanic mudflows) originating on Mount Rainier during the last 10,000 years have moved down valley floors and buried them under meters of rock debris. These lahars devastated existing forests and their deposits provided new substrate for primary succession. Many lahar surfaces on Mount Rainier have been dated (Crandell 1971). Recent lahars occurred in all the valleys, but did not reach lower, forested areas of the Ohanapecosh and Carbon River valleys. The Osceola mudflow in the White and West Fork valleys evidently originated in avalanches of hydrothermally altered rock near the summit of Mount Rainier about 5,700 years ago. It is one of the largest lahars known in the world; its tremendous volume might represent the former summit of Mount Rainier (Crandell 1971). Effects of smaller lahars on forests are shown by the 1947 Kautz lahar in the Nisqually drainage on which forests are now in early successional stages (Fig. 3).

Other recent mass wasting processes that start forest succession include large landslides, and more localized rock debris flows, talus slides, and floods. Some of the major landslides are ancient relative to

Figure 3. Mudflows have periodically destroyed forests in some of the major river valleys. Kautz Creek mudflow, pictured here in 1978, occurred in October of 1947 and killed most of the trees by burying their root systems.

the ages of the oldest forests we studied (Fiske et al. 1963) and are covered by layers of pyroclastic deposits. On steeper slopes, however, where colluvial processes are active, soils commonly consist of mixtures of volcanic ash and rock fragments. Important, too, are the relief and drainage features created by these mass wasting or slump processes on forested slopes (Swanston and Swanson 1976). Slow drainage on closed depressions (such as benches) and very rapid drainage of taluses are good examples.

Glacial, glacial-outwash, and alluvial landforms are common at all forested elevations on Mount Rainier. Rates of forest establishment on high elevation moraines have been measured by Sigafoos and Hendricks (1972). Complex interbeddings of alluvial and lahar deposits are found along the lower valleys (the lahar assemblages of Crandell 1971). Glacial outburst floods (Richardson 1968) may cut away existing river terraces and create new ones as substrates for new forest successions. Surficial deposits of glacial origin include a wide variety of drift materials (Crandell and Miller 1974). Many of these are buried under recent

volcanic ash, and are not important as soil substrates. But some of our forest plots are located in landscapes topographically or edaphically controlled by these older drifts. At limited locations in the *Tsuga mertensiana* Zone, more recent drifts (McNeeley and Garda Drifts) are found, but most of the Holocene deposits are within the subalpine parkland outside the closed forest region of this study.

Topography

The topography of the forested valleys and slopes around Mount Rainier is very rugged because the landscape is comparatively youthful (Fig. 4). Steep runoff and erosion gradients exist along the flanks of this 4394-m (14,410-ft) volcano. The variety of geomorphic processes shaping the landscape include volcanic, glacial, fluvial, mass wasting, and other erosion processes described earlier. The resultant topography exists in scales ranging in magnitude from kilometers (for major landform features) to meters (microrelief).

At elevations below 1000 m (3,500 ft), broad valleys radiating from the volcanic cone are separated by steep to vertical canyon walls. Nearly flat or very gentle slopes characterize the alluvial and lahar deposits on these valley floors, with hummocky microrelief at the smaller scale. Lower valley sideslopes are of moderate to severe steepness, especially where glaciers or streams exerted intense, downcutting activity.

Cliffs and ledgy canyon sidewalls are particularly conspicuous, for example, in the Ohanapecosh drainage. At smaller scales, hillslope erosion and mass wasting have created systems of ridges and depressions and local, benchy topography on these sideslopes (Swanston and Swanson 1976).

The forested midelevations of 1000 to 1350 m (3,500 to 4,500 ft) present certain topographic contrasts to the lowlands. Streambed gradients of valleys are steeper; in places, spectacular, entrenched rivers are illustrated by such features as the Box Canyon of the Cowlitz. Valley profiles within major drainages may present more abrupt contrast between valley flows, narrow toeslopes, and steep sidewalls. Cliffs and falls are common. The canyon slopes present a complex local relief of draws and downsloping ridges, benchy and uneven topography.

The upper elevation forests above 1350 m (4,500 ft) are commonly found on the upper surfaces of volcanic flows and within cirques of upper glacial basins. Relief varies from nearly flat (for example, Grand Park) to gentle, undulating topography. The steep and very steep topography of midelevations is less prevalent. Upper slopes and ridges are common. Glacial basins and morainal features are dissected by snowmelt and runoff channels. Other local topographic features include

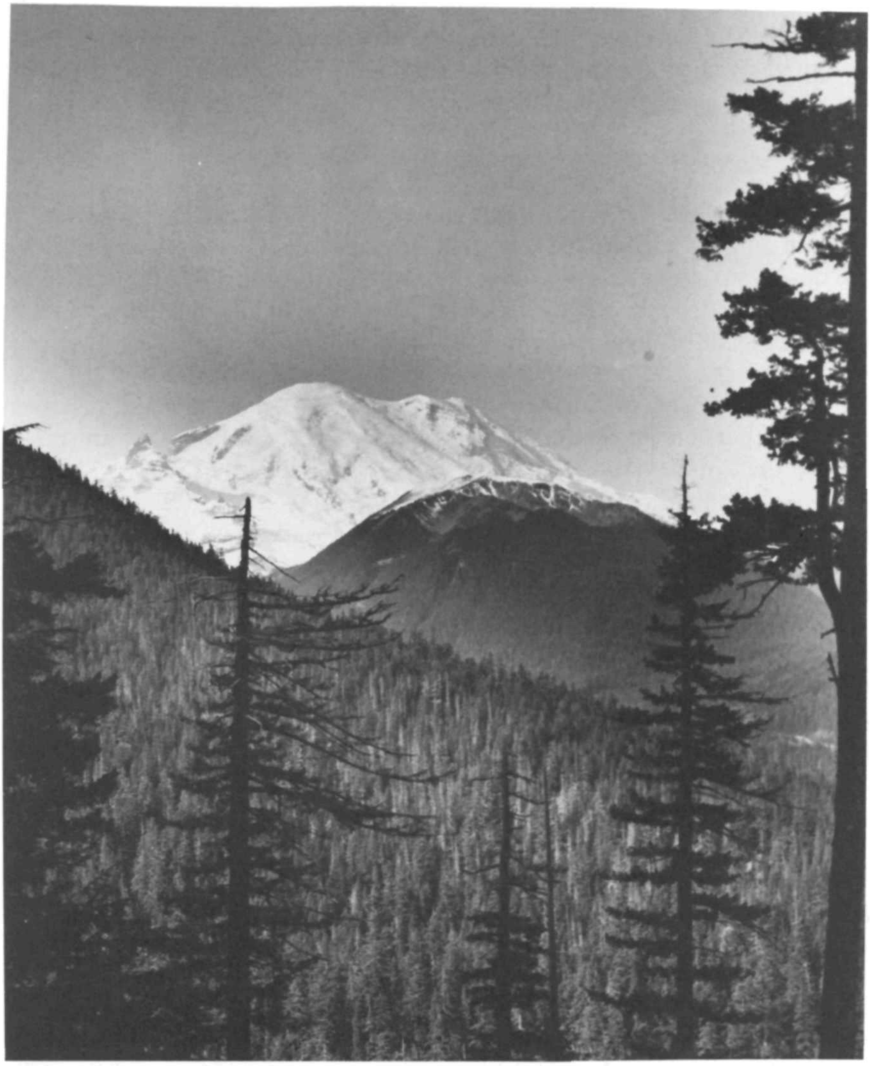


Figure 4. Forests typically occupy rugged mountain slopes and ridgetops in Mount Rainier National Park. A portion of the White River valley.

rock outcrops (along Pinnacle Peak trail in the Tatoosh Range, for example), rock avalanche and talus slopes, and rough broken land along upper valley slopes.

The distribution of topographic relief features according to elevation determines the shape of the forest-environment diagrams provided in Chapter 6 (see, e.g., Fig. 34). Upper slopes and ridgetops are more

characteristic of upper elevations, whereas broad valley bottoms, streamside terraces, and river bars are most important at the lower. But each of the major forested drainages around Mount Rainier present differences in topography which account for the shape of each diagram.

Soils

The soils of the Park have not been described in published literature. Franklin (1966) recognized the podzolic nature of many soil profiles and described numerous buried soil horizons resulting from successive volcanic ash deposits. Data from similar soils in the northern Washington Cascade Range indicate that such soils fit all but one criterion for classification into the Spodosol order (Singer and Ugolini 1974). The accumulations of surface organic horizons, development of iron pans, and particle movement from eluvial to illuvial horizons are typical features of soil profiles (Franklin 1966, Hobson 1976).

All soil parent materials in the Park are of Holocene age. Profiles have developed in materials of glacial, alluvial, colluvial, or pyroclastic origin. Topography and geographic locations relative to eruptive sources of pyroclastic particles are major determinants of soil parent material composition. The most common soil parent materials are the pyroclastic deposits (tephras)[1] erupted from Mount Rainier, Mount St. Helens, and, less commonly, Mount Mazama. Mullineaux (1974) and Hobson (1976) describe the distribution of these pyroclastics in our study area and their importance as soil parent materials. Hobson (1976) classified Mount Rainier soils on the basis of geological origin, relief, and drainage features. His system was adopted for this report.

Tephra soils can be identified by individual ash layers (Mullineaux 1974) differentiated by color, texture, and presence or absence of lapilli (Fig. 5). Many possible combinations of ash layers are found in profiles because of the nature of tephra distribution in this region, the presence of lithic layers between tephras, and various mixing and local redistribution processes associated with topographic relief (Hobson 1976). Furthermore, any particular pyroclastic deposit might bury the existing forest soil profile in either intact or altered condition. Colluvial material might also be found within or between various tephra layers, but generally comprise less than about 2 percent of the soil volume. At wetter sites internal drainage might be moderately or strongly impeded by iron pan development. On relatively hot, dry sites drainage is usually good, and development of podzolic A2–B2 horizon sequences may be weak.

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[1]Tephra refers to all types of volcanic ejecta (e.g., ash or pumice) that are aerially deposited on the landscape.

Figure 5. Many of the soils in Mount Rainier National Park are formed in pyroclastic materials such as the conspicuous tephra W, the whitish deposit, underlain by coarse-textured lapilli of the tephra C.

Tephra soils are very common in the forests. The following profiles indicate typical features of these soils. The first profile was found beneath an *Abies amabilis/Rhododendron albiflorum* community near Narada Falls (Franklin 1966):

Horizon	Depth (Centimeters)	Description
01	9–7	Matted needles, leaves, and twigs; pH 4.7.
02	7–0	Densely matted decomposing and humidified organic matter with abundant roots; pH 4.2.
A21	0–2	Gray, coarse sand; single grain; 1–7 cm thick; pH 4.2; abrupt wavy lower boundary.
A22	2–5	Very dark gray, coarse sand; single grain; 1–7 cm thick; pH 4.4; abrupt wavy lower boundary.
B21	5–15	Very dark brown, gravelly sandy loam; moderate medium subangular blocky structure; 8–25 cm thick; 26 percent pumice lapilli; 7.8 percent organic matter; many distinct mottles of very dark gray brown and few of dark reddish brown and dark gray; roots, rotting wood, and charcoal abundant; pH 4.9; clear irregular boundary.
B22	15–20	Very dark gray-brown to gray sandy loam; weak, fine subangular blocky structure; 1–8 cm thick; 16 percent pumice lapilli; many fine to coarse indistinct mottles of very dark brown; charcoal, roots, and rotting wood common; pH 4.9; abrupt wavy boundary.
IIB23	20–57	Mosaic of yellowish red and dark brown, coarse sand; moderate medium subangular blocky structure; 12.8 percent organic matter; charcoal common at top and bottom; roots occasional; pH 4.9; abrupt smooth boundary.
IIIB24g	57–90	Very dark gray, sandy clay loam; massive breaking to moderate medium to coarse subangular blocky structure; 8.7 percent organic matter; abundant distinct coarse layers and mottles of very dusky gray and black (organic matter and charcoal); few distinct coarse mottles of dark gray brown or gray; few fine roots in upper 3 cm of horizon; pH 5.1; abrupt wavy boundary.
IVB3	90–105+	Dark yellowish brown, very rocky loamy sand; massive, very firm; 85 percent rocks and gravel by volume, rocks andesitic breccia, subangular to rounded, and up to 35 cm long; rocks form line at top of horizon; 6 percent organic matter; many distinct fine to coarse mottles of dark reddish brown (rotting wood); iron staining around rocks; no roots; pH 5.3.

This profile, taken from a river terrace along Fryingpan Creek (see Fig. 5), shows the relationships between pyroclastic deposits (Mullineaux 1974) and soil horizons in even more detail:

Pyroclastic deposit	Depth (Centimeters)	Soil horizon
Not applicable	12–0	01 and 02
Post W	0–2	A21
W	2–8	IIA22
Pre-W	8–12	IIIA21b
C	12–20	IVBirb
C	20–35	IVC1b
C + unknown	35–47	VC2b
P + unknown	47–57	VIC3b
Unknown + Y	57–77	VIIC4b

Colluvial soils are the dominant soil group in the Park. Hobson (1976) describes these as unstable soils, rapidly drained, and consisting of coarse, unconsolidated, mixed parent materials. They are found on slopes at all elevations, but especially the steeper slopes and south-facing aspects. Colluvial soils intergrade with tephra soils, but are identified primarily by the mixing of pyroclastic and nonpyroclastic materials. The pyroclastic materials are minimally layered, and where several ash deposits exist they are generally well mixed. Notable exceptions occur in colluvial soils having an unmixed tephra W surface layer or tephra Y sublayer. The following profile was considered by Hobson (1976) to be representative of colluvial soils in the Park. It is found under an *Abies amabilis/Xerophyllum tenax* community on a steep mid-slope on Rampart Ridge:

Horizon	Depth (Centimeters)	Description
01	9–7	Litter
02	7–0	Duff, roots common
A21	0–2	Dark gray, fine sand (post-W tephra); loose; roots common; abrupt smooth boundary with
IIA22	2–5	Mixed gray and yellowish brown, coarse sand (tephra W); single grained; roots common; abrupt irregular boundary with
IIIB	5–60	Yellowish brown, gravelly sand; 25 percent lapilli and angular gravels increasing with depth; loose; roots abundant at 40 cm grading to few at 50 cm.

Alluvial soils occur in major river valleys, along lesser streamsides, on wet benches where fine-textured water-deposited materials are often mixed or interbedded with tephras, and on alluvial slopes and fans. Soil materials are often in stratified, water-laid layers on depositional landforms. Along the floodplains of broader valleys, centuries of deposition and subsequent downcutting by rivers produced terraces well above the present-day stream channels. Elsewhere, alluvial deposits have been formed by glacial outburst floods or by ephemeral streams carrying snowmelt discharge from upper slopes. Depositional sequences of alluvial materials vary considerably in thickness and textures. Various surface or subsurface strata may consist of skeletal, cobbly sands, coarse undifferentiated sand, and fine or very fine sands. Deposition may also have resulted in patterns of mounds and depressions, whose microrelief presents strong contrasts in soil moisture and drainage. Some alluvial soils exhibit A1 horizon, others may have subsurface gleyed horizons. Many can be classified as Fluvents (Soil Survey Staff 1975). The following example of an alluvial soil is from a *Tsuga heterophylla/Oplopanax horridum* community on a river bar at the Grove of the Patriarchs:

Horizon	Depth (Centimeters)	Description
01/02	3–0	Organic horizons
A1	0–3	Very dark brown, fine sand; moderate medium crumb structure very friable; fine roots common; boundary clear and smooth with
	3–14	Dark yellowish brown, fine sand; massive, breaking to moderate coarse subangular blocky structure; very friable; fine roots common, few medium roots; boundary smooth and clear with
IIC	14–65+	Dark gray sand; massive breaking to single grain structure; few roots; some variation in texture with depth suggests several alluvial deposits.

Mudflow soils are Hobson's (1976) fourth group. Surface or subsurface parent materials within the rooting zone are of laharic origin. The soils may also contain tephra W or alluvial or colluvial surface deposits. In such cases, the presence of rounded rocks or boulders on or beneath the surface help identify mudflow soils. Soil profiles range from totally undifferentiated to displaying well-developed horizons, as

given in the example below. Old lahar surfaces in major valleys often have surficial alluvial deposits, so that soils may closely resemble the group of alluvial soils described above. The following profile was found under an *Abies amabilis/Vaccinium alaskaense* community on an upper slope near Round Pass and belongs to Hobson's group of mudflow soils:

Horizon	Depth (Centimeters)	Description
01	9–8	Litter mat
02	8–0	Compacted humus with abundant roots
A2	0–6	Very dark gray, fine loamy sand; medium and fine roots abundant; boundary wavy and clear with
B2lir	6–17	Dark reddish brown, fine sandy loam; moderate medium coarse subangular blocky structure, firm or very firm; iron concretions common; few fine roots, mostly along ped faces; boundary wavy and clear with
B22	17–36	Dark brown, cobbly, gravelly, loamy sand; massive breaking to weak medium and coarse subangular blocky structure; very friable; pumice grains about 5 mm diameter are well weathered; cobbles 15–20 percent; medium and fine roots common; boundary abrupt and irregular with
C	36–51+	Dark gray brown, cobbly, gravelly, loamy sand; massive; iron-stained concretions about 6–7 mm diameter at boundary with B22; cobbles plus gravels 50–60 percent by volume; no roots.

Hobson's classification of soils did not include all the soil types we encountered in this study. Miscellaneous soils included Entosolic profiles of recent moraines and drifts, and occasional peaty or deep humic soils along streams within the *Tsuga mertensiana* Zone.

Chapter 3
Biological Features

The diversity of the flora and fauna in Mount Rainier National Park reflects the Park's great environmental and elevational range. General features of the vegetation, as understood from past studies, are briefly reviewed here. Detailed discussions of disturbance and succession are found in Chapter 7.

Vegetation

Closed coniferous forests and subalpine and alpine meadow communities are the major plant formations in the Park. The forests occupy about 60 percent of the Park landscape, extending to elevations of about 1600 m (5,250 ft) on the western and 2000 m (6,000 ft) on the northeastern slopes of the volcano. Parklands (mosaics of forest patches, tree clumps, and meadows) extend above the forest line for another 300 m (1,000 ft) (Fig. 6). Ice, permanent snowfields, rock, and barren ground predominate above about 2500 m (8,200 ft).

The forests of the Park are part of the coniferous forest formation of the world. Regionally, these forests have been described by dominance of *Pseudotsuga menziesii* within *Tsuga heterophylla-Thuja plicata* climaxes (Franklin and Dyrness 1973), and as being part of the *Tsuga heterophylla* and *Tsuga mertensiana* ecogeographic provinces (Daubenmire 1978). These stands are known for their density, productivity, nearly complete conifer dominance, and the size and longevity of the dominant tree species. Most coniferous genera find their largest and often longest lived representatives in these forests, including *Pseudotsuga, Tsuga, Abies, Chamaecyparis, Picea, Pinus*, and *Thuja* (Fig. 7). Forest productivity and the massive accumulations of wood relate to the attainable sizes and ages as well as the relatively moderate winter temperatures and dry summers characteristic of the region (Waring and Franklin 1979).

Figure 6. Parkland mosaics of tree stringers and patches and subalpine meadows extend about 300 m (1,000 ft) above forest line with permanent snowfields, rock, and barren ground common above the parkland. Headwaters of Nickel Creek.

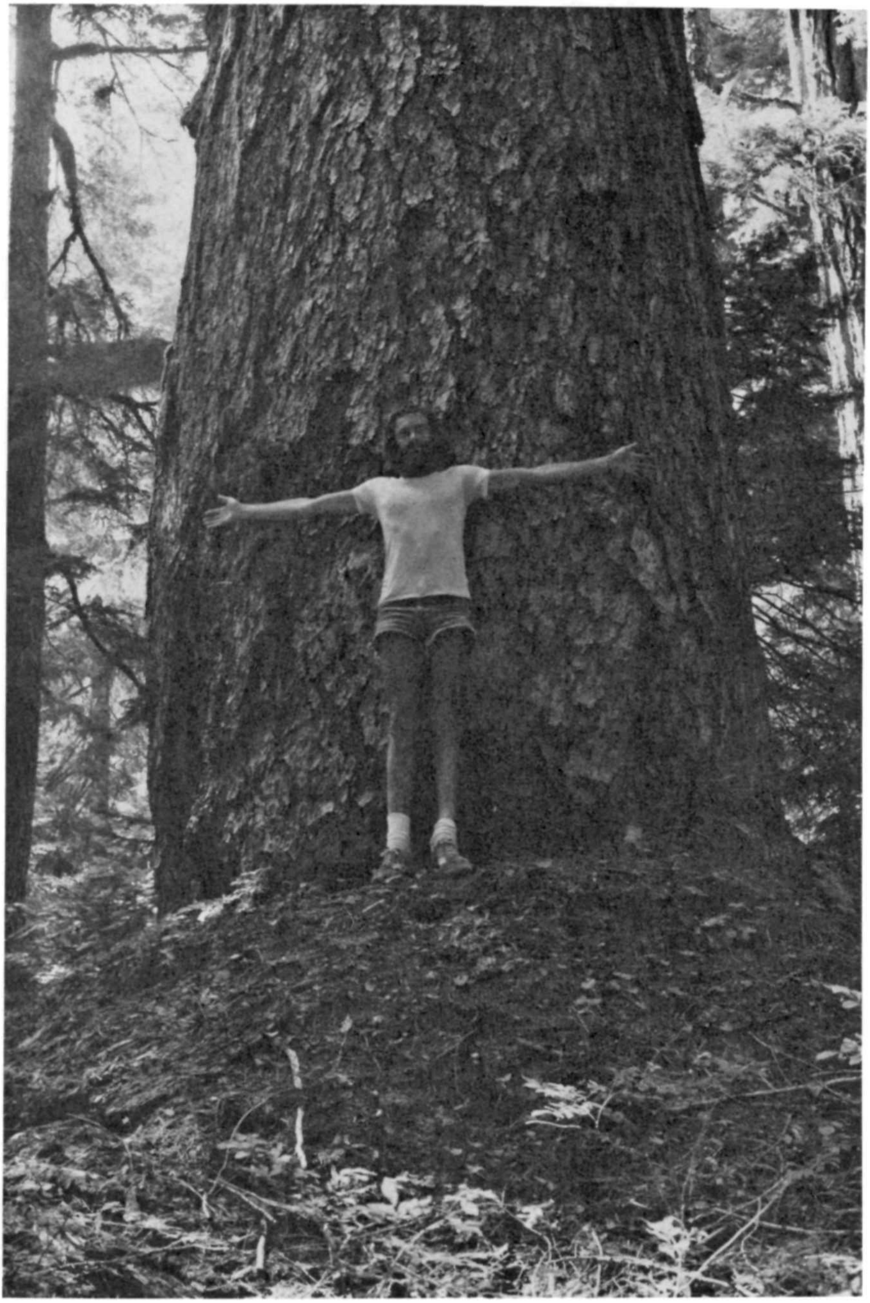

Figure 7. This massive 1,000-year-old Douglas-fir grows in a stand of the *Abies amabilis/ Vaccinium alaskaense* habitat type along the upper Ohanapecosh River.

Variation in the forests of this region relate mainly to three factors: temperature regime, moisture (including snow) regime, and the length of time the forest has gone undisturbed. Disturbance will be discussed in the next section. Temperature is primarily responsible for the strong changes in forest conditions associated with elevation; these changes are typically described as belts or zones (see, for example, Zobel et al. 1976). There are three forest zones in the Park: *Tsuga heterophylla*, *Abies amabilis*, and *Tsuga mertensiana* (Franklin and Bishop 1969). The *Tsuga heterophylla* Zone is a part of Daubenmire's (1978) "Temperate Mesophytic Forest Region" and "*Tsuga heterophylla* Province" which he describes as having the most luxuriant conifer forest in the world. The *Tsuga mertensiana* Zone is a part of the "Subarctic-Subalpine Forest Region" and "*Tsuga mertensiana* Province" which extends from California to Alaska (Daubenmire 1978). We consider the *Abies amabilis* Zone to be cool temperate rather than subalpine; it is not explicitly recognized by Daubenmire (1978).

Substantial permanent winter snowpacks are characteristic of both the *Abies amabilis* and *Tsuga mertensiana* Zones, with much greater depths and durations in the latter. In both zones depth and duration of snowpack are important factors differentiating forest community types (Brooke et al. 1970, Long 1976). Moisture regime during the dry summer months appears to be the most important factor affecting the forest patterns in the *Tsuga heterophylla* Zone (Zobel et al. 1976).

Forests in the Park have been the subject of numerous general accounts, including those of Plummer (1900), Foster (1911), Brockman (1933, 1947, and 1949), and Franklin and Bishop (1969). Brockman (1931) also did a classification of forest cover types and a map of the Park. Most of these accounts cover only the broad patterns of tree species occurrence. The major tree species in the Park are *Abies amabilis*, *Abies grandis*, *Abies lasiocarpa*, *Abies procera*, *Chamaecyparis nootkatensis*, *Picea engelmannii*, *Pinus albicaulis*, *Pinus contorta*, *Pinus monticola*, *Pseudotsuga mensiesii*, *Tsuga heterophylla*, *Tsuga mertensiana*, and *Thuja plicata*. Rare tree species include *Picea sitchensis* in the Carbon River drainage and *Pinus ponderosa* on the east side of the Park.

In addition, several detailed studies have examined the vegetation in areas adjacent to the Park. Franklin (1966) provides a general forest-association-habitat type classification for the southern Washington-northern Oregon Cascade Range, including Mount Rainier. Thornburgh (1969) includes considerable autecological study of tree species as well as information on stand ages and dynamics. Long (1976) reports the forest communities found in the Cedar River drainage thirty miles north of the Park. Henderson and Peter (1981) and Brockway et al. (1983) provide comprehensive classifications of the plant associations

and habitat types in the White River drainage and on the Gifford Pinchot National Forest, respectively, both locales bordering the Park. All five of these papers include considerations of forest succession, especially the climax role of *Abies amabilis* and its relation of succession to other tree species. Other papers of interest include Higinbotham and Higinbotham (1954) on forest mosses; del Moral et al. (1976) and del Moral and Watson (1978) on the central Washington Cascade Range community mosaic; and Kotor (1972) on the ecological relationships of *Abies amabilis*.

The subalpine and alpine meadow vegetation is well known for its diversity and aesthetic qualities. Scientific studies include those of Henderson (1973) and Hamann (1972) on the plant community types, Franklin et al. (1967) on meadow invasion by trees, and Edwards (1980) on visitor impacts in alpine regions. Major categories of subalpine meadows are (1) Heather-huckleberry (*Phyllodoce-Cassiope-Vaccinium*), (2) Black sedge (*Carex nigricans*), (3) Green fescue (*Festuca viridula*), lush herbaceous (*Valeriana-Veratrum*), and "rawmark" or early successional community (*Saxifraga tolmei*). The distributional patterns of these communities are determined largely by the depth and duration of snowpack.

Disturbances to Vegetation

Elapsed time since the last major disturbance largely determines stage of vegetational succession and is the third important factor influencing the composition and structure of the existing forests in the Park. Agents that disturb or destroy forests include wildfire, snow and rock avalanches, volcanic eruptions, mudflows, floods, and wind. Following a severe disturbance, a site is typically occupied by a series of non-forested communities (for example, herb- and shrub-dominated types) before forest cover is reestablished. The initial or pioneer forest often includes, and may be dominated by, shade-intolerant tree species such as *Pseudotsuga menziesii* and *Pinus* spp. With time, such light-requiring species are gradually replaced by shade-tolerant species that can reproduce in the understory of a closed-canopy forest. *Tsuga heterophylla* and *Abies amabilis* are examples of shade-tolerant species capable of forming self-perpetuating or climax types that remain constant in composition.

The history of disturbance to forests in the Park has been reconstructed by Hemstrom (1979) and Hemstrom and Franklin (1982); a map showing the major forest age classes in the Park is included as Plate 2. Wildfire has been the most important forest-destroying agent near Mount Rainier and has affected all but a small fraction of the forest area during the last 1,000 years. Some of the wildfires appear to

have been very large (>10,000 ha) and affected several quadrats of the Park. The fire history is discussed in detail in Chapter 7.

In recent times, portions of the Ohanapecosh drainage burned in 1803 and much of the Cowlitz drainage burned in 1856 and again in 1866 (Plummer 1900). Burns occurred on Crystal Mountain and Sourdough Mountain in 1858, in Sunset Park in 1930, and at Shriner Peak in 1934. A long natural fire rotation (around 465 years) is indicated for the Park, although the expected fire frequency ranges widely with local site conditions (Hemstrom 1982). There are correlations between major episodes of fire and periods of prolonged drought.

The rate of revegetation following wildfires is highly variable and depends on many factors, including availability of seed source and local site conditions. Single wildfires often regenerate rapidly from residual trees, but forests are often slow to reclaim areas burned two or more times within a few decades (Franklin and Dyrness 1973). Both residual and peripheral seed sources are lost in reburns, along with any existing regeneration. Sites with harsh environments, such as droughty south slopes or cold, snowy habitats, typically regenerate more slowly than sites with favorable moisture and temperature conditions (Fig. 8).

Lahars and mudflows have occasionally devastated forests along lower slopes and alluvial flats (Crandell 1971). The Kautz lahar of 1947 is a conspicuous example (see Fig. 3). Mortality of large old-growth trees resulted from both physical uprooting and suffocation following root burial. Succession proceeds from initial stands of *Alnus rubra*, *Alnus sitchensis* (at higher elevations), *Salix* spp., *Pteridium aquilinum*, *Epilobium angustifolium*, and *Anaphalis margaritacea* to mature forests of various types. An example of old forests developed on lahar material can be seen at Cougar Rocks campground, where some pioneering *Pseudotsuga menziesii* have reached 1,000 years of age on a lahar deposit of about the same age (Crandell 1971, Hemstrom 1979).

Avalanches cause extensive forest disturbance (Fig. 9), especially at high and intermediate elevations where slope angle, anchoring vegetation, and snow accumulation patterns are susceptible (Luckman 1978). Avalanche tracks stand out on aerial photographs as their boundaries contrast sharply with the less regular fire boundaries. Avalanches rank second to fire in terms of forest area disturbed in the Park. Vegetation communities and successional dynamics on avalanche tracks have been the subject of dedicated study by Cushman (1981).

Windthrow may be extensive in some areas, but it is difficult to isolate from other disturbances. It leaves no distinguishing boundaries and only occasionally destroys whole stands. Other factors, such as insect kills and root rot pockets, may seriously weaken trees which then blow down. Since its effects separate poorly from those of other events, the total impact of windthrow is difficult to estimate.

Figure 8. Forest reestablishment is typically slow on harsh sites and following multiple wildfires; both conditions exist on this site near Louise Lake, which is still only partially forested almost 100 years after it burned (in 1886 or 1887).

Other types of disturbance include glacial advances, and river activities such as flooding and terrace cutting.

Some venerable forests in the Park have survived centuries of hazard to attain ages of more than 1,000 years (see Plate 2). Large trees over 1,000 years old (mostly *Pseudotsuga menziesii* and *Chamaecyparis nootkatensis*) sit in antiquity where portions of the Ohanapecosh, Cow-

Figure 9. Snow avalanches are second only to wildfire as an agent of forest destruction; tracks may be kept clear of forest by annual avalanches or eliminate forests developed on less frequently affected tracks such as this one near Spray Park.

litz, Nisqually, and Carbon drainages have been protected from disturbance. The Park's oldest trees are *Chamaecyparis*, over 1,200 years old in the Ipsut Creek valley.

As mentioned, tree species differ in their successional roles and those have been well described for the montane forests of the Cascade Range (see, for example, Franklin 1966, Thornburgh 1969, Kotor

1972, and Long 1976). A brief overview is provided here; a more comprehensive discussion is in Chapter 6. The very shade-tolerant *Abies amabilis* and *Tsuga heterophylla* are the major climax species. The *Abies* generally replaces the *Tsuga* at higher elevations (over 1000 m or 3,300 ft) with several proposed explanations (see, e.g., Thornburgh 1969, Long 1976). *Pseudotsuga menziesii, Pinus monticola, Pinus contorta, Abies procera*, and *Abies lasiocarpa* are considered seral or pioneer species, subject to successional replacement. *Thuja plicata, Chamaecyparis nootkatensis, Tsuga mertensiana*, and *Picea engelmannii* are usually considered to be of intermediate status, perhaps capable of playing some climax role in the forest mosaic in the Park. It is important to note that almost any species can appear in early successional forests provided seed source is available. Pioneer forests on many sites can be composed of *Abies amabilis* or *Tsuga heterophylla* as well as *Pseudotsuga mensiesii* or *Abies procera*.

Chapter 4
Methods

Our general methodology was essentially the same as that widely applied in forest classification in the western United States (Pfister and Arno 1980) and in the USDA Forest Service Area Ecology Program (see, e.g., Henderson and Peter 1981). More comprehensive discussions of the philosophy underlying such studies can be found in these and related references.

Field Sampling

Our sampling was designed to cover the full range of forest types in all sectors of the Park and throughout each forest zone. Stands were sampled, therefore, by a reconnaissance technique modified from Dyrness et al. (1974). The field crew traveled a slope, trail, road segment, or path through the forested landscape and established a sequence of sample plots that revealed both typical and changing forest patterns. Whenever major changes in dominance relationships of tree or understory vegetation were observed along these routes, the crew would look for a forest stand of sufficient size and homogeneity to establish a sample plot. The plots were usually circular and 500 or 1000 m^2 (0.125 or 0.25 acre) in size, depending on the densities of the larger sized trees. Additional plots from Franklin's (1966) earlier study were included. Stands ranged in age from about 70 years to over 1,000 years since major disturbance, but all presented essentially a forest environment mostly characterized by a closed or semiclosed tree canopy. In some places, especially at higher elevations or on more exposed sites, the field crew sampled more open forests if understory vegetation generally resembled that of closed forests. A total of 518 plots provided the basis for the classification presented here.

In each circular plot, all tree stems exceeding 1.4 m (4.5 ft) in height were tallied by species and diameter at breast height (d.b.h.) by diameter classes of 1-dm (4-in) intervals. We defined "established

seedlings" as trees between 1 and 14 dm (4 and 55 in) in height, and counted these in either a 50-m^2 (545-ft^2) circular plot at the center of the larger plot or at four 12.5-m^2 (136-ft^2) circular plots in each quadrant of the larger plot.

Understory herbs and shrubs were recorded by the extent of their canopy coverage; this was estimated visually over the entire plot to the nearest percent for species with less than 10 percent cover, and to the nearest 5 or 10 percent for those with over 10 percent cover.

Soil types (Hobson 1976) and general morphological features were described from small pits (usually one per plot) located in areas of typical understory vegetation. Other environmental data collected at each plot included: elevation, exposure, slope, landform, position in landscape (lower, middle, upper slope, bench, ridge, valley), and location on a U.S. Geological Survey topographic map. Conspicuous or unusual features of forest stands were described as notes or remarks. These included evidence of fire, influence of animals, windthrow, mosaics, and ecotones with other forest types.

Stand ages were estimated from increment cores of dominant trees judged to be among the first wave of regeneration after disturbance. Rings from cored trees were counted in the field. Age was estimated from the ring count plus corrections for center and age-to-core height. Generally, the older trees of a cohort were sought in order to determine a time limit for whatever disturbance gave the opportunity to establish that cohort. When available, ring and age data from stumps or cut sections of tree falls along trails were also useful for estimating cohort ages.

Data Analysis

Our classification of the forests at Mount Rainier was an interactive procedure between plot sorting based on field judgments and data analyses and displays from a computer (Franklin et al. 1970, Pfister and Arno 1980). The first 400 plots were used in steps 1 through 10. Specific steps were as follows:

1. Initial synthesis tables were developed by manual sorting. At the end of each field season, plots were organized into tables according to dominant, diagnostic features of tree, shrub, and herb vegetation (Shimwell 1972). The major features we used were tree species present in seedling and sapling size classes and dominant shrub and herb species.
2. Data were coded, edited, and verified for computer processing. The entire data set was too massive for computer handling, so we simplified it for the initial analysis. For example, minor species (those that occurred in less than 1 or 2 percent of the plots) were excluded. Certain more common species not thought to

have classificatory significance were also excluded. These were species with a wide ecological amplitude and low site indicator value, such as *Epilobium angustifolium* and *Goodyera repens*.

3. Environmental plot groupings were developed. Plots were assigned into four groups approximating the major environmental regimes of the forests at Mount Rainier (moist, modal, dry, and cold). Each group contained up to 125 plots, and doubtful plots were assigned to more than one group. Each group was subject to the similarity and principal component analyses described below.
4. Similarity matrices were computed for all plots for each environmental group. The index of similarity was that of program SIMORD (Dyrness et al. 1974)—a percentage similarity (Sorensen's index) based on dominance of selected tree and understory species. Species chosen for similarity computations were thought, in our judgment, to have possible classificatory significance by their restricted distributions. Different sets of species were used in each of the four groups.
5. Initial plot clusters were extracted. Highly similar plots representing typal communities (Daubenmire 1966) were sought from each group similarity matrix. Our field judgment and the initial groups (step 1) were necessary for the initial discrimination of these clusters of "modal plots." Generally the plot similarities within the initial clusters exceeded 30 and sometimes 40 percent.
6. Diagnostic vegetative and environmental features of the modal plot clusters were identified and incorporated into abstracts of each tentative type.
7. Plot clusters were expanded. The modal plots of step 5 did not contain the full range of variation of forest vegetation or environments. The similarity matrix was further examined for unassigned plots having mostly intermediate similarities (20- to 30-percent) to plots of the modal clusters. The unassigned plots were classified into a forest grouping whenever the diagnostic or environmental features of the appropriate modal cluster (step 6) were satisfied. This step involved considerable ecological judgment for those plots having only weak expressions of the diagnostic criteria.
8. The reduced similarity matrix for ungrouped plots were examined for further typal communities. Steps 5–7 were repeated until a small residue of unassigned plots remained; these were considered intergrades or unclassifiable as unique stands.
9. Revised synthesis tables were constructed for the emerging similarity groupings. The similarity matrix was reorganized to display similarities in intergroupings and intragroupings. The stand

tables and reorganized similarity matrix were then used to check for anomalous or misclassified plots and possible reassignment (Franklin et al. 1970, Pfister and Arno 1980). Again, field experience and subjective judgments were sometimes needed to confirm or change the assignment of plots difficult to classify. Plots that were typically difficult to assign were stands with depauperate understories as a result of dense tree canopies.

10. Principal component analysis (PCA) was carried out with species correlation matrices (R-matrix) computed within each environmental group (step 3) using the same classifier species characteristics employed for similarity analysis. The R-matrix was used for the axis extraction procedures of PCA (Cooley and Lohnes 1971).
11. Discriminant analysis was performed on 19 forest groups defined after step 9 was completed. Discriminating variables were selected among those species that had high values of importance in the initial stand tables of step 1; 39 species were used. Discriminant functions were computed by procedures described in the "Statistical Package for the Social Sciences" (Nie et al. 1975) to optimize separation of the 19 groups in multivariate space. To provide an independent test of the classification, over 100 additional plots (plot nos. 401–518), which had *never* been used in the analysis to this point, were classified according to the discriminant functions. In an additional test, all of the plots already assigned to forest groups by similarity procedures (step 9) were subjected to discriminant analysis. This reexamination revealed less than 5 percent of the plots had a high probability of misclassification. Such plots were reexamined and, when warranted by ecological judgment based on information not used in discriminant analysis (such as soil type), were either reassigned to another forest type, kept in the assigned type, or not classified.
12. Once step 11 was completed, the final synthesis and summary tables were prepared using all 518 plots. Synthesis tables were printed by computer for the full set of data for each forest type. The printouts also tabulated slope-corrected densities for established seedlings, saplings (0–20 cm or 0–8 in d.b.h.), poles (20–50 cm or 8–20 in d.b.h.), and standards (d.b.h. over 50 cm or 20 in). Tree densities by 10-cm (4-in) d.b.h. size classes and basal area were also printed for every plot within each forest type (trees over 120 cm or about 50 in d.b.h. were printed individually). Canopy coverage of understory shrubs and herbs (arranged alphabetically) were tabulated by plot. These tables are on file at the Forestry Sciences Laboratory, Corvallis, Oregon, and at the headquarters of Mount Rainier National Park.

We also prepared a directory of plots and summary tables for each forest type, except for several minor types. The directory tabulates location and environmental data for each plot and provides a listing of plots within each forest type. The summary tables contain data averaged over all plots within each forest type. Summaries for trees include slope-corrected densities and basal areas. Summaries for major or descriptive shrubs or herbs (106 taxa are tabulated) include constance (the percentage of plots containing a taxon) and percent canopy cover (averaged over all the plots within each forest type and not just over plots on which it occurred). Total shrub and total herb cover percents are the sums of the average cover percent for tabulated shrub and herb species (the nontabulated understory plants contribute little average cover to the forest types).

The entire plot data set is available at cost on magnetic tapes from the Forestry Sciences Data Bank, Forest Science Department, Oregon State University, Corvallis, Oregon 97331.

Terminology and Nomenclature

Our classification uses terms now standardized in the western United States (Daubenmire and Daubenmire 1968, Pfister et al. 1977, Pfister and Arno 1980, Layser and Schubert 1979, Henderson and Peter 1981). This discussion of the vegetative classification hierarchy is taken largely from Henderson and Peter (1981). The major units of interest to us are plant community type, plant association, plant series, and habitat type (Fig. 10). Plant community types are aggregations of plant communities (the actual stands observed and sampled in the landscape) that are judged to be very similar based upon analyses of the type outlined in the previous section. When a plant community type is based upon mature or old-growth stands and emphasizes the stable or potential climax components, it is termed a plant association. The plant association is, then, a special type of plant community, i.e., a climax plant community. Plant associations can be aggregrated into plant series (Fig. 10) which, in forests of the western United States, turn out to be groupings of plant associations with the same dominant climax tree species. Geographic varieties of a major plant association are sometimes recognized as phases. The plant association characterizes a particular kind of environment and can therefore be used as a basis for distinguishing land areas of differing environments and biological potential. All of the land area capable of supporting the same plant association or climax vegetation is called a habitat type (Fig. 10). The habitat type is named for its potential vegetation, a practice which sometimes leads to a confusion between something which is a plant community type (association) and an actual land area which may or

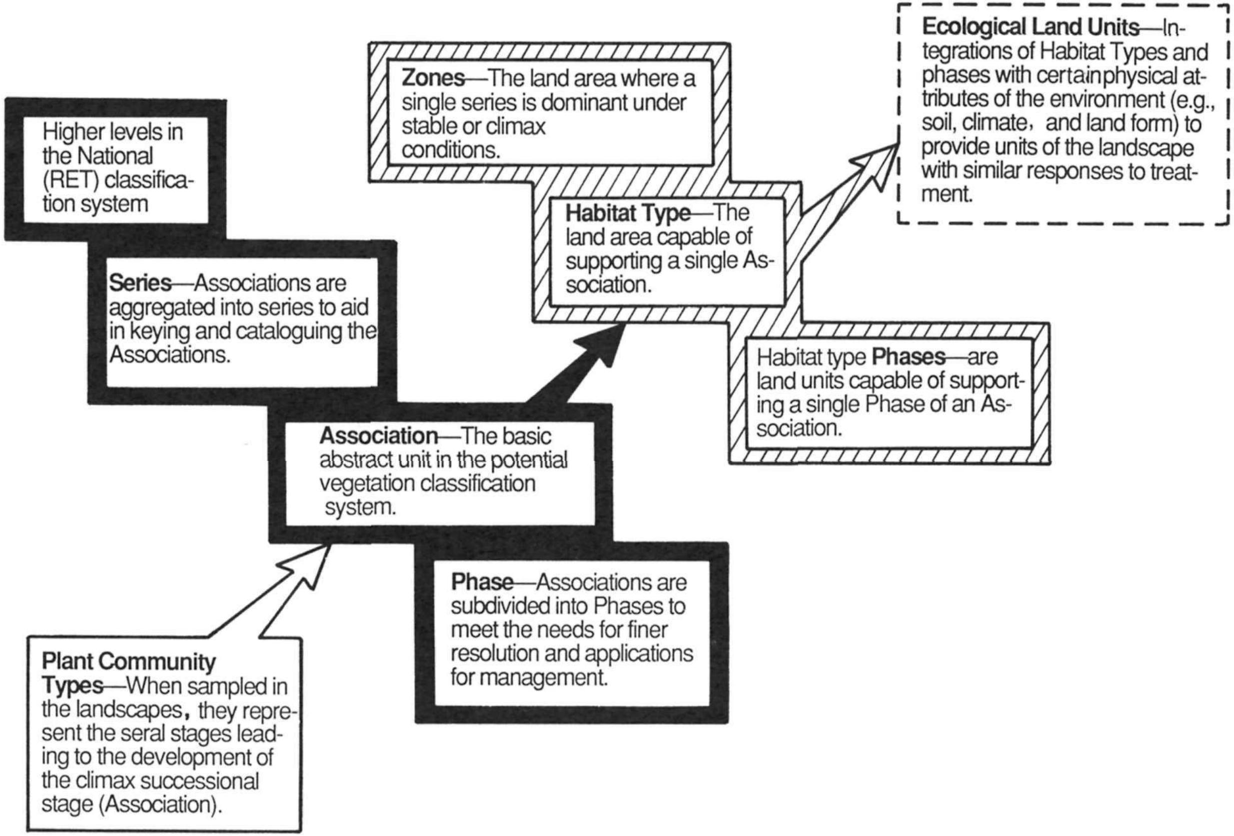

Figure 10. The classification hierarchy (from Henderson and Peter 1981).

may not currently be occupied by that vegetation. A zone has the same relation to habitat type that series has to plant association.

The final synthesis tables (see step 12 in the previous section) provide the basis for identifying the major forest communities in Mount Rainier National Park. Fourteen of these communities are plant associations based upon mature and old-growth forest stands. We considered mature forests to be 200 years or more in age and in which (1) tree population structures suggest the ultimate climax species composition and (2) the understory is relatively stable, at least in dominance relationships among the major species. Associations are sometimes divided into phases to reflect minor but consistent geographic, environmental, and floristic variations in the basic type. Obviously, a plant association can be used to distinguish land areas of similar ecologic potential, i.e. a habitat type, and, as mentioned, the habitat type is named for its distinguishing (but sometimes absent) plant association.

Some early successional or young stands could not readily be related floristically or environmentally to plant associations. Consequently, five community types are identified in our Mount Rainier classification. These types represent the most general level in the hierarchy (Fig. 10); they are immature, unstable communities and are expected to evolve into one or more of the plant associations over time. The value of these communities as environmental indicators is obviously limited and they do not distinguish a habitat type.

The emphasis on older forest stands and potential vegetation (plant associations) is because of their value as indicators of environmental conditions. Early successional species, including seral tree species, are commonly generalists with broad ecological amplitudes. Later successional species tend to be much more attuned to local environmental conditions and have, therefore, much greater value in locating oneself on an environmental field (see, e.g., Zobel et al. 1976).

Nomenclature of each plant association is typically a binomial. The first name consists of a leading climax tree or sometimes a leading associated late seral or co-climax tree. The tree portion of the name is followed by a slash, then by a major, diagnostic understory species. Community types were named by the leading seral tree, followed next by a slash, then by a major diagnostic understory species. In many illustrations and tables we have used abbreviations for the species that comprise the names of habitat and community types. These abbreviations are defined on the inside front cover.

Chapter 5
Forest Classification

Our classification consists of 14 plant associations and 5 community types in Mount Rainier National Park (Table 1). Several of these have phases to identify subtypes. In addition, separate data are provided for seral groupings (consisting mostly of immature forest stands) of plots representative of several associations. Several minor forest communities are recognized which occur on special soils or landforms or which have restricted distribution in the Park.

We must remind readers that our plant associations are regarded as vegetational expressions of particular environments or habitat types (see previous chapter). The location of 14 of the associations within an idealized environmental field is illustrated in Figure 11. Correspondence

Table 1. Classification of forests in Mount Rainier National Park.

Association, community type[1], or phase and abbreviation	No. of plots sampled	Forest zone[2]
1. *Tsuga heterophylla/Achlys triphylla* Association (TSHE/ACTR)	9	TSHE
2. *Tsuga heterophylla/Polystichum munitum* Association (TSHE/POMU)		
a. *Tsuga heterophylla* phase	12	TSHE
b. *Abies amabilis* phase	10	ABAM
3. *Tsuga heterophylla/Oplopanax horridum* Association (TSHE/OPHO)	26	TSHE
4. *Alnus rubra/Rubus spectabilis* Community Type (ALRU/RUSP)	4	TSHE, ABAM
5. *Abies amabilis/Oplopanax horridum* Association (ABAM/OPHO)		
a. Valley phase	19	ABAM
b. Slope phase	14	ABAM

Table 1. Continued

Association, community type[1], or phase and abbreviation	No. of plots sampled	Forest zone[2]
6. *Abies amabilis/Tiarella unifoliata* Association (ABAM/TIUN)		
a. Climax phase	32	ABAM
b. Seral phase	7	ABAM
7. *Abies amabilis/Vaccinium alaskaense* Association (ABAM/VAAL)		
a. *Vaccinium alaskaense* phase	43	ABAM
b. *Berberis nervosa* phase	19	ABAM
c. *Rubus pedatus* phase	19	ABAM
d. *Chamaecyparis nootkatensis* phase	6	ABAM
8. *Tsuga heterophylla/Gaultheria shallon* Association (TSHE/GASH)	17	TSHE
9. *Pseudotsuga menziesii/Ceanothus velutinus* Community Type (PSME/CEVE)	6	TSHE, ABAM
10. *Pseudotsuga menziesii/Xerophyllum tenax* Community Type (PSME/XETE)	17	ABAM
11. *Pseudotsuga menziesii/Viola sempervirens* Community Type (PSME/VISE)	18	ABAM
12. *Abies amabilis/Gaultheria shallon* Association (ABAM/GASH)	15	ABAM
13. *Abies amabilis/Berberis nervosa* Association (ABAM/BENE)	38	ABAM
14. *Abies amabilis/Xerophyllum tenax* Association (ABAM/XETE)		
a. *Tsuga heterophylla* phase	14	ABAM
b. *Tsuga mertensiana* phase	11	TSME
c. Seral phase	7	ABAM
15. *Abies amabilis/Rubus lasiococcus* Association (ABAM/RULA)		
a. *Rubus lasiococcus* phase	27	ABAM, TSME
b. *Erythronium montanum* phase	24	TSME
16. *Abies lasiocarpa/Valeriana sitchensis* Community Type (ABLA2/VASI)	21	TSME
17. *Abies amabilis/Rhododendron albiflorum* Association (ABAM/RHAL)	25	TSME
18. *Chamaecyparis nootkatensis/Vaccinium ovalifolium* Association (CHNO/VAOV)	15	TSME
19. *Abies amabilis/Menziesia ferruginea* Association (ABAM/MEFE)		
a. Climax phase	20	ABAM, TSME
b. Seral phase	7	ABAM, TSME

[1]Stands less than 200 years old.
[2]ABAM = *Abies amabilis*, TSHE = *Tsuga heterophylla*, TSME = *Tsuga mertensiana*.

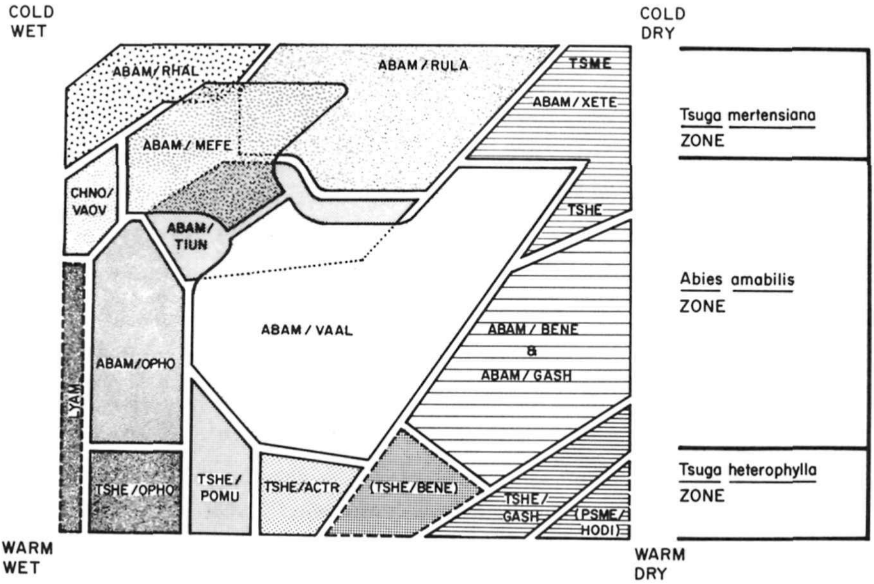

Figure 11. Generalized distribution of habitat types in relation to an idealized two-dimensional environmental field. The horizontal axis represents a moisture gradient and the vertical axis a temperature gradient that is correlated to elevation and forest zones. Because the moisture span may not be as broad at high elevations as it is at low, the rectangular shape of the environmental field is merely for visual convenience (see Fig. 34 for detailed example). Diagonal boundaries between habitat types suggest general effects of slope; for example, the warm, dry environment of a habitat type may be found at higher elevations on southerly slopes, and cool, wet environment of a habitat type at lower elevations on northerly slopes. Minor forest types are not shown except for localized swamp forests on wettest sites at low and intermediate elevations. The *Tsuga heterophylla/Berberis nervosa* and *Pseudotsuga menziesii/Holodiscus discolor* habitat types have not been found within the Park but occur on adjacent forest lands. Abbreviations are defined on the inside front cover.

between the associations and traditional forest zones is also shown in Figure 11 and Table 1. The patterns of plant association distribution over elevational and topographic gradients will be discussed in more detail in Chapter 6.

Each of the forest associations and community types (collectively referred to hereafter as forest types) is discussed in this chapter. Descriptions of each forest type include general environmental conditions, geographic range within the Park, and tree and understory composition. Successional patterns are considered primarily in Chapter 7. Management implications are considered in Chapter 8. Tables 2 through 10 summarize quantitative details for each forest type. The appendix contains keys to and a brief synopsis of each forest type. The general

geography and importance of the forest associations is illustrated by Plate 1. A directory of the individual plots, their locations, and characteristics is available on request from Dr. Jerry F. Franklin, College of Forest Resources, AR-10, University of Washington, Seattle, WA 98195.

In the discussions of each forest type, we point out relationships to other forest types both within the Park and on a broader geographic basis. We regard forest types to be related by several criteria. They may share many, though not all, dominance relationships among tree and understory species. Hence there is a high degree of floristic similarity, especially among the species important in characterizing the forest types being compared. Secondly, the forest types being compared on a broad geographic basis may share many environmental features, although we usually lack data to make precise comparisons or to analyze compensating environmental features at different locations. On a narrower geographic basis (for example, within Mount Rainier National Park), forest types can be related by either of these criteria, but we have the additional advantage of being able to observe ecotones or to firm up the relationship by identifying plots which are gradational in either floristic or environmental characteristics.

Forest types are arbitrarily grouped into five categories so that closely related types are together (Table 1); the association and stand tables are also organized by these groups. Types could sometimes have been assigned to either of two groups (e.g., *Abies amabilis/Xerophyllum tenax* to either the dry or cold group); such types are included in both appropriate association tables for the reader's convenience in comparing related types. All three of the *Pseudotsuga menziesii* communities are included in the dry group so that they can be discussed together.

Moist Forest Ecosystems

Five associations and one community type are included in the wet to moist group of forest communities (Table 1). These types occupy habitats where trees rarely encounter significant moisture stress and represent a moderate elevational gradient (Fig. 11). Understories are typically lush, which may reflect the favorable moisture conditions. Extremely wet forests or swamps are briefly discussed in the section on "Other Forest Communities."

Tree data (average size class distributions, percent presence, and average basal area) are presented for this group of forest communities in Tables 2 and 3. Presence and average cover of shrubs and herbs in the wet habitat group are presented in Table 4.

Table 2. Average basal area by tree species for all forest types, Mount Rainier National Park[1]

Species	Forest type[2]													
	1	2a	2b	3	4	5a	5b	6a	6b	7a	7b	7c	7d	8
Abies amabilis	0.5	0.5	10.4	5.4	0.5	24.3	46.8	37.2	63.1	23.9	11.9	31.5	1	0.5
Abies grandis				1.9										0.0
Abies lasiocarpa					0.1			1.0	0.3					
Abies procera	1.1					0.1	5.0	20.3	63.1	2.8	0.6	5.0		
Alnus rubra	0.1			1.5	23.8		2.2							
Chamaecyparis nootkatensis		0.0	0.0			2.4	2.6	5.3	3.9	1.7	0.0	3.2	18.9	0.0
Picea engelmannii						0.5	3.1	1.5						
Picea sitchensis				6.4										
Pinus albicaulis														
Pinus contorta														
Pinus monticola	1.3									0.3	0.0			0.0
Populus trichocarpa				0.6										
Pseudotsuga menziesii	57.3	106.4	16.9	34.7	7.9	22.6	0.1	11.3	6.2	18.1	30.4	9.1	14.3	33.5
Thuja plicata	9.1	21.8	8.1	27.0		15.4	7.1	0.0		5.8	7.0	1.9		3.5
Tsuga heterophylla	17.1	33.2	41.3	27.4	0.6	40.3	17.5	20.7	7.2	32.6	33.5	34.1	29.7	16.9
Tsuga mertensiana							0.1	2.2		1.1	0.0	0.1	8.4	
All species[3]	86.5	162.0	76.6	104.9	32.9	105.6	84.5	99.5	97.7	86.2	83.4	84.9	81.2	54.4

Species	Forest type[2]														
	9	10	11	12	13	14a	14b	14c	15a	15b	16	17	18	19a	19b
Abies amabilis	0.5	0.9	0.4	3.0	4.2	6.7	49.1	11.8	38.8	55.0	4.6	34.5	30.4	43.2	19.8
Abies grandis			0.1												
Abies lasiocarpa		0.2	0.0		0.1	0.0	1.9	16.8	2.7	4.0	54.6				1.8
Abies procera	2.3	1.5	0.4	0.6	6.3	19.9	10.6	0.1	1.8	2.4	0.6	0.5	0.4		5.1
Alnus rubra			0.0												
Chamaecyparis nootkatensis	0.3	0.1	0.0	0.9	0.8	3.6	2.6	0.4	16.9	6.7	1.2	14.9	35.4	12.0	3.1
Picea engelmannii		0.0	0.1		0.0				1.1	0.0	2.6		2.6		0.5
Picea sitchensis															
Pinus albicaulis											0.5				
Pinus contorta		0.1													
Pinus monticola	0.7	0.5	0.0	0.0	1.0	1.2	0.0	0.9	0.0	0.4		0.6	0.1		0.1
Populus trichocarpa			0.1												
Pseudotsuga menziesii	5.5	17.6	41.2	17.8	47.5	18.3	0.1	11.3	12.5	1.1	2.8	1.0		7.6	2.8
Thuja plicata		0.0	2.1	7.3	4.2	0.4		0.1	0.6			0.0		0.0	1.4
Tsuga heterophylla	0.1	2.9	2.2	42.6	34.2	47.4	3.3	6.0	8.0	0.9	0.3	2.7	6.9	19.9	14.4
Tsuga mertensiana	0.0	1.3	0.0			4.2	4.5	1.0	5.0	24.5	0.9	26.9	22.9	8.3	1.7
All species[3]	9.4	25.0	46.7	72.2	98.3	101.7	72.2	48.5	87.4	95.1	68.1	81.1	98.7	91.1	50.8

[1]Average basal area values are m^2 ha^{-1}. Blanks indicate that the species was not sampled in the type. The value 0.0 indicates that the species either occurred with average basal area that rounded to 0.0, or that the species occurred only as seedlings which have no basal area at 1.4 m.

[2]Forest type numbers correspond with those given in Table 1.

[3]Columns do not necessarily total exactly due to round off error.

Table 3. Average tree density (stems per hectare) for the moist forest types by species and stem-diameter class, Mount Rainier National Park.

Type and species[1]	Con[2]	Basal area[3]	≤1[5] ≤1.4 m	≤1[5] >1.4 m	Stem-diameter class[4] 1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	>12
Tsuga heterophylla/Achlys triphylla Association																
Pseudotsuga menziesii	89	57.3			5	5	16	32	21	14	13	16	10	8	2	7
Tsuga heterophylla	89	17.1	10,489	119	34	25	11	6	6	3	4	6		2		2
Abies amabilis	78	0.5	200	27	7	2	2									
Thuja plicata	44	9.1	356			2	9	2		2			2	2		2
Abies procera	22	1.1	67			2					2					
Pinus monticola	11	1.3										2				
Alnus rubra	11	0.1		7		2										
All species[6]		86.5	11,111	152	46	39	39	40	27	20	19	24	13	13	2	12
Tsuga heterophylla/Polystichum munitum Association, *Tsuga heterophylla* Phase																
Pseudotsuga menziesii	100	106.4					5	5	2	9	15	6	5	5	2	33
Tsuga heterophylla	100	33.2	3,583	138	56	39	22	21	4	11	8	4	1	3	3	4
Thuja plicata	67	21.8		8	6	6	2				2	3		2	3	9
Abies amabilis	42	0.5	133	63	10	3	1									
Chamaecyparis nootkatensis	8	0.0	17													
All species[6]		162.0	3,733	208	72	48	30	27	6	20	25	13	6	11	7	47
Tsuga heterophylla/Polystichum munitum Association, *Abies amabilis* Phase																
Tsuga heterophylla	100	41.3	7,340	734	76	27	27	19	11	12	8	13	6	7	1	1
Abies amabilis	80	10.4	4,080	66	23	14	15	2	9	8	2		2			
Thuja plicata	70	8.1	80	8	7	2	6	2		6	2		2			1
Pseudotsuga menziesii	30	16.9	60							4	2		2	1		5
Chamaecyparis nootkatensis	10	0.0	20													
All species[6]		76.6	11,580	809	106	43	48	24	19	30	15	13	13	8	1	7
Tsuga heterophylla/Oplopanax horridum Association																
Tsuga heterophylla	96	27.4	4,669	267	44	28	21	15	19	8	5	6	2		2	2
Thuja plicata	88	27.0	54	19	11	8	3	4	3	3	2	3		2	1	10
Pseudotsuga menziesii	58	34.7	123	1		2	3	3	2	6	5	2	2	2		10
Abies amabilis	35	5.4	123	16	8	3	5	5	2	2	3	2				
Abies grandis	31	1.9	454	2	2		2	1	2	1						
Picea sitchensis	19	6.4	23	2	4	3	1	1				1	1			3
Alnus rubra	19	1.5					2	2	3	1						
Populus trichocarpa	8	0.6		2									1			
All species[6]		104.9	5,446	309	68	44	38	32	30	21	15	14	7	4	3	25
Alnus rubra Community Type																
Alnus rubra	100	23.8		30	45	85	75	40	15	5						
Tsuga heterophylla	50	0.6	250	30	5		5									
Abies amabilis	50	0.5		15	10	5										
Pseudotsuga menziesii	25	7.9				25	15	5			10					
Abies lasiocarpa	25	0.1			5											
All species[6]		32.9	250	75	65	115	95	45	15	5	10					
Abies amabilis/Oplopanax horridum Association, Valley Phase																
Tsuga heterophylla	100	40.3	5,095	209	37	22	16	10	7	14	8	9	3	2	3	7
Abies amabilis	100	24.3	6,253	546	83	36	24	13	9	9	6	8	2		1	
Thuja plicata	53	15.4	105	5	1	2	1	1	3	2		3	1	1	1	5
Pseudotsuga menziesii	42	22.6	21	1		2	1	2	2	3					1	9
Chamaecyparis nootkatensis	11	2.4		9	5	4	3	2			1			1		
Picea engelmannii	5	0.5					2		1							
Abies procera	5	0.1					1									
All species[6]		105.6	11,474	769	126	66	48	28	22	28	15	20	5	3	6	21

Table 3. Continued

Type and species[1]	Con[2]	Basal area[3]	≤1[5] ≤1.4 m	≤1[5] >1.4 m	Stem-diameter class[4] 1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	>12
Abies amabilis/Oplopanax horridum Association, Slope Phase																
Abies amabilis	100	46.8	4,114	679	85	40	33	15	25	10	9	17	10	1	2	3
Tsuga heterophylla	93	17.5	1,314	194	27	14	23	4	5	6				1	1	4
Thuja plicata	21	7.1	14	5			5			2			2			2
Abies procera	21	5.0				2			1	1	1					2
Chamaecyparis nootkatensis	21	2.6	57	22	2	6	3	2	3			2				
Tsuga mertensiana	14	0.1	57	5	3											
Picea engelmannii	7	3.1	29													2
Alnus rubra	7	2.2					23									
Pseudotsuga menziesii	7	0.1					2									
All species[6]		84.5	5,586	905	116	61	89	20	33	19	10	18	12	2	3	13
Abies amabilis/Tiarella unifoliata Association, Climax Phase																
Abies amabilis	100	37.2	5,350	531	70	27	16	14	21	13	15	12	5	1	2	
Tsuga heterophylla	75	20.7	656	142	32	12	12	6	9	2	4	3	2	2	3	3
Abies procera	47	20.3	75	7				2	1	3	3	3	2	2	4	5
Chamaecyparis nootkatensis	31	5.3	81	10	1	2	3	5	3	2	1	1		1		1
Pseudotsuga menziesii	25	11.3		10	4	4	1	3	4	3	1	1	2			3
Tsuga mertensiana	25	2.2	100	7	1		1	1						2		
Abies lasiocarpa	9	1.0		3		1		1	1		1					
Thuja plicata	9	0.0	6	2												
Picea engelmannii	3	1.5	13				1		1		1			1		
All species[6]		99.5	6,281	711	108	47	33	32	39	22	26	19	11	8	8	13
Abies amabilis/Tiarella unifoliata Association, *Abies procera* Phase																
Abies procera	100	63.1	29	10	10	44	53	60	26	9	15	3	25	3	3	3
Abies amabilis	100	17.1	4,000	581	120	37	7	19	19	6		3				
Tsuga heterophylla	71	7.2	657	110	29	7	3	3	7			7				
Pseudotsuga menziesii	57	6.2					3	3		3	3				3	
Chamaecyparis nootkatensis	14	3.9	257	37	20	27	17	3								
Abies lasiocarpa	14	0.3				7										
All species[6]		97.7	4,943	737	179	121	83	89	51	18	18	13	25	3	6	3

[1]Species are ordered within type by constancy.
[2]Constancy, expressed as percent of sample containing the species.
[3]Expressed as meters squared per hectare.
[4]Decimeters (dm) in diameter at breast height (1.4 m above the ground).
[5]The ≤1 dm diameter class is subdivided into two classes based on height.
[6]Column sums may not be exact due to rounding error.

Table 4. Constancy and characteristic cover of all shrub and herb taxa for the moist forest community types of Mount Rainier National Park.

	Community type[1]																	
	1.		2a. TSHE/POMU		2b. TSHE/POMU		3.		4.		5a. ABAM/OPHO		5b. ABAM/OPHO		6a. ABAM/TIUN		6b. ABAM/TIUN	
	TSHE/ ACTR		TSHE phase		ABAM phase		TSHE/ OPHO		ALRU/ RUSP		Valley phase		Slope phase		Climax phase		Seral phase	
Number of plots per type:	9		12		10		26		4		19		14		32		7	
Taxa	Con	Cov[2]	Con	Cov	Con	Cov	Con	Cov	Con	Cov	Con	Cov	Con	Cov	Con	Cov	Con	Cov
SHRUBS																		
Cornus nuttallii	22	2																
Holodiscus discolor	11	T	8	T														
Ribes viscosissimum			8	T														
Symphoricarpos albus	11	T			10	T												
Gaultheria shallon	78	5	25	T	20	1	23	3			11	T						
Gaultheria ovatifolia	56	1	8	T			4	T					7	T	3	2		
Rubus leucodermis					10	T												
Rubus nivalis	44	T	8	3	10	T	15	2			5	3			3	T		
Rubus ursinus	100	1	33	T	10	T	23	2			11	1			13	1		
Amelanchier alnifolia	33	T							25	1							14	T
Berberis nervosa	100	3	83	12	70	7	35	3			11	4	7	T	9	3	29	1
Symphoricarpos mollis	56	1									5	14			3	1	14	1
Taxus brevifolia	44	6	50	8	50	2	15	T			26	3	7	5	3	T		
Rhamnus purshiana							4	1										
Acer glabrum	11	1					4	3					7	3				
Vaccinium parvifolium	100	3	83	1	100	3	77	1	50	2	63	1	29	T	13	1	14	T
Chimaphila umbellata	89	T	33	1	40	T	12	T			16	T	7	T	13	1	57	2
Rosa gymnocarpa	100	1	17	T			35	T	25	T	16	T	14	T	9	1	57	2
Acer circinatum	100	37	42	9	20	T	88	18	75	6	26	4	21	11	25	8	43	6
Lonicera ciliosa	11	T													3	T		
Chimaphila menziesii	67	T	50	1	70	T	23	T			47	T	14	T	25	T	57	T
Cornus canadensis	78	4	33	T	20	T	35	1	25	5	79	4	50	1	16	3	29	5
Prunus spp.									25	T								
Vaccinium alaskaense	78	1	50	4	60	1	38	7	25	1	100	12	64	6	34	1		
Sambucus spp.			8	T	30	T	50	1	75	2	21	1	64	2	6	1		
Alnus sinuata			8	1			4	8					7	T	3	T		
Rubus spectabilis	11	T	42	T	50	T	69	2	100	48	68	3	93	3	31	1		
Oplopanax horridum			50	T	60	T	100	11	100	18	100	11	100	15	44	T	14	T
Menziesia ferruginea	33	1	17	T	50	T	27	T	50	1	53	2	50	1	25	4	29	T
Rubus pedatus	44	1	42	1	60	T	58	4			95	7	93	4	78	6	14	4
Ribes bracteosum							4	T	50	27	5	1	7	4	3	T		
Rubus parviflorus	22	8	8	T	20	T	23	T	50	2	11	4	50	1	16	1	57	1
Vaccinium ovalifolium	33	T	50	T	40	T	54	1	50	2	89	4	71	7	72	3	57	1
Salix scouleriana							4	T			5	T			3	6		
Ribes lacustre			25	T			46	1	25	T	42	1	79	2	31	1	29	T
Ribes spp.									25	1					3	T		
Rubus lasiococcus	89	1					4	T	25	10	47	3	79	3	84	6	86	7
Pachistima myrsinites	22	T											7	T	9	T	43	T
Vaccinium membranaceum	56	2			10	T	8	T	25	1	32	1	57	2	78	4	100	6
Sorbus sitchensis	33	T					4	T	25	T	21	1	29	T	38	1	86	1
Viburnum edule											5	T	7	T	6	1		
Rhododendron albiflorum													7	T	16	8		
Rubus idaeus															3	T		
Corylus cornuta															3	T		
Vaccinium scoparium															3	4		

Table 4. Continued

	Community type[1]																	
	1.		2a. TSHE/POMU		2b. TSHE/POMU		3.		4.		5a. ABAM/OPHO		5b. ABAM/OPHO		6a. ABAM/TIUN		6b. ABAM/TIUN	
	TSHE/ ACTR		TSHE phase		ABAM phase		TSHE/ OPHO		ALRU/ RUSP		Valley phase		Slope phase		Climax phase		Seral phase	
Number of plots per type:	9		12		10		26		4		19		14		32		7	
Taxa	Con	Cov[2]	Con	Cov	Con	Cov	Con	Cov	Con	Cov	Con	Cov	Con	Cov	Con	Cov	Con	Cov
HERBS																		
Pyrola aphylla	11	T																
Parnassia fimbriata			8	T														
Heuchera spp.			8	T														
Festuca occidentalis	11	T					4	T										
Osmorhiza depauperata					10	T												
Gilia spp.			8	T			4	1										
Allotropa virgata					10	T												
Polypodium glycyrrhiza	11	T	25	T	40	T	12	1			16	T						
Trisetum cernuum	11	T									5	1						
Monotropa uniflora	11	T	17	T							16	T						
Tiarella laciniata							8	1										
Corallorhiza maculata							4	T										
Tolmiea menziesii					10	T	31	7	25	25								
Pyrola virens	22	T	8	T	20	T	4	T			16	T			3	1		
Pyrola picta	22	T	8	T	30	T	4	T			5	T			3	T	14	T
Montia siberica							12	3										
Campanula scouleri	11	T	8	T													14	T
Bromus suksdorfii							8	T										
Agastache spp.							4	T										
Polystichum lonchitis	11	T	33	T	30	T	12	T			5	T	21	T	3	T		
Dryopteris austriaca	22	T	25	T	20	T	35	T			11	2	21	T			14	T
Pteridium aquilinum	78	1					12	3	25	20					6	11	43	1
Oxalis oregana					10	4	23	57	25	2	5	25						
Circaea alpina	22	T			10	T	62	12	75	23	11	1	14	5				
Adenocaulon bicolor	44	4	33	T	20	1	65	2	50	1	16	1	7	T	16	2	14	1
Pyrola uniflora			17	T			12	1			11	T	7	T				
Polystichum munitum	56	1	100	18	100	5	96	8	75	T	58	1	50	1	31	1	14	T
Corallorhiza spp.	44	T			10	T	8	T			16	T	14	T	6	T		
Lysichitum americanum							12	6			5	8						
Hydrophyllum spp.							50	1			11	T					14	T
Petasites frigida					10	5	8	T	25	T			7	5				
Lycopodium clavatum			8	T	10	T					16	1						
Festuca subulata	11	T					15	2	25	1	5	1	14	T				
Blechnum spicant	22	1	75	2	90	10	50	2			68	5	50	2	22	1		
Cystopteris fragilis	11	T	8	T			4	T	25	T	5	T	7	T	3	2		
Listera borealis	89	4	58	2	40	11	35	2	25	2	79	6	21	2	16	3	71	T
Stachys ciliata							12	1	25	5			7	1				
Anemone deltoidea	33	T	25	T			38	4			11	1			9	T	57	T
Epilobium angustifolium					10	T	15	T	25	T			7	T	3	T		
Tiarella trifoliata	22	T	100	8	80	4	92	15			63	11	57	1	44	1	29	3
Galium triflorum	44	1	67	T	60	1	81	3	100	1	32	1	71	1	31	T	43	T
Corydalis scouleri			8	T	40	T	42	13	75	1	21	7	14	1	13	4		
Carex spp.			8	T	10	T	42	1	50	T	11	T	14	T	9	T		
Disporum hookeri	89	T	33	T	20	T	50	T			37	1	50	1	28	1	43	T
Elymus glaucus									25	3								
Stellaria crispa							8	3	25	T			7	T				
Senecio spp.			8	T											3	T		
Anaphalis margaritacea					10	T							7	T				
Goodyera oblongifolia	100	T	75	T	80	T	38	T			63	T	36	T	41	T	100	T

Table 4. Continued

	Community type[1]																	
	1.		2a. TSHE/POMU		2b. TSHE/POMU		3.		4.		5a. ABAM/OPHO		5b. ABAM/OPHO		6a. ABAM/TIUN		6b. ABAM/TIUN	
	TSHE/ ACTR		TSHE phase		ABAM phase		TSHE/ OPHO		ALRU/ RUSP		Valley phase		Slope phase		Climax phase		Seral phase	
Number of plots per type:	9		12		10		26		4		19		14		32		7	
Taxa	Con	Cov[2]	Con	Cov	Con	Cov	Con	Cov	Con	Cov	Con	Cov	Con	Cov	Con	Cov	Con	Cov
Habernaria orbiculata							4	T			5	T						
Claytonia parvifolia									25	2								
Carex mertensii									25	T								
Madia dissitiflora	22	T	25	1	30	T	46	T			47	1	29	2	19	T		
Aster modestus									25	1								
Galium boreale									25	3								
Ranunculus spp.									25	1								
Adiantum pedatum							23	1	25	1			21	T				
Hieracium albiflorum	44	2	33	T	30	T	19	T	25	T	5	T	21	T	22	T	43	1
Streptopus amplexifolius			42	T	60	T	58	T	75	T	42	T	50	1	22	T	14	1
Montia spp.	11	T	17	T			58	2	75	14			50	2	16	T		
Pyrola asarifolia	22	T							25	T	11	T			3	T	14	T
Trifolium latifolium	56	2	8	2	10	T	15	1			5	T	7	1	19	T	43	1
Athyrium filix-femina	11	T	83	T	50	T	92	7	100	14	84	4	93	4	44	4	14	T
Habenaria saccata					10	T	8	T			11	T	14	1				
Actaea rubra	22	T	17	T	10	2	19	T	25	T	32	T	36	T	9	T	14	T
Listera cordata	56	T	42	T	50	T	31	T	25	T	68	1	29	1	44	T	29	T
Fragaria vesca	11	T	8	T			8	T	25	T			7	T	6	T	14	T
Smilacina stellata	78	2	58	T	20	1	69	3	75	1	53	3	57	6	47	7	100	6
Streptopus streptopoides			17	T	50	T	8	3			26	1	14	1	19	1		
Viola sempervirens	100	7	75	2	80	1	31	2	25	2	58	2	64	2	69	2	100	1
Achlys triphylla	100	26	67	4	70	1	85	11	75	33	84	12	93	15	81	15	86	18
Trillium ovatum	89	T	83	T	80	T	65	T	50	1	95	1	100	1	78	T	86	T
Luzula parviflora			8	T	40	T	27	T			11	1	36	1	19	2		
Gymnocarpium dryopteris	11	T	50	37	60	4	85	28	75	7	95	15	86	24	59	5		
Dicentra formosa							4	T					7	2				
Epilobium alpinum							8	T					14	1				
Aster canescens	11	T			30	T	42	1	50	T	16	T	64	2	19	3	14	3
Cinna latifolia									50	17			7	1				
Equisetum fluviatile							4	T	25	T	5	T	14	T				
Tiarella unifoliata	67	3	58	5	60	1	65	11	100	7	84	7	100	13	100	14	86	9
Clintonia uniflora	67	1	50	T	30	T	54	1	25	1	95	3	86	4	75	5	86	6
Galium oreganum	11	6	8	T			15	1	50	1	5	2	14	T	16	1	29	2
Saxifraga arguta											5	T						
Pterospora spp.											5	T						
Poa nervosa											5	T						
Calypso bulbosa											5	T						
Aruncus sylvester			8	1									7	T			14	T
Anemone lyallii	22	T									11	T			6	1	29	1
Osmorhiza spp.	22	1	8	T	20	T	54	1	75	2	26	T	50	1	56	3	43	T
Mitella spp.			8	T			38	4	50	14	26	2	50	3	31	1		
Streptopus roseus			42	2	60	T	50	1	25	T	95	5	86	7	81	10	29	T
Viola glabella	22	2	8	T	10	T	62	4	100	11	53	1	86	5	53	6	57	1
Bromus vulgaris	22	7			10	T	35	1	75	1	16	T	29	1	28	1	71	T
Stipa occidentalis											16	2	7	T				
Lithospermum californicum	33	T	8	T	20	T	8	T	25	1	58	T	36	T	38	T	57	T
Pyrola secunda	11	T	25	T	40	T	12	T			53	T	50	1	63	1	86	2
Xerophyllum tenax	22	1							25	T					13	3	43	T
Pedicularis racemosa	11	T													3	T	29	T
Arenaria macrophylla	11	T					4	T					14	T	9	1	29	T
Smilacina racemosa	11	T			10	T					11	T	29	T	9	T	43	T

Table 4. Continued

	Community type[1]																	
	1.		2a. TSHE/POMU		2b. TSHE/POMU		3.		4.		5a. ABAM/OPHO		5b. ABAM/OPHO		6a. ABAM/TIUN		6b. ABAM/TIUN	
	TSHE/ ACTR		TSHE phase		ABAM phase		TSHE/ OPHO		ALRU/ RUSP		Valley phase		Slope phase		Climax phase		Seral phase	
Number of plots per type:	9		12		10		26		4		19		14		32		7	
Taxa	Con	Cov[2]	Con	Cov	Con	Cov	Con	Cov	Con	Cov	Con	Cov	Con	Cov	Con	Cov	Con	Cov
Trautvetteria grandis							4	T	25	1	16	T	43	4	19	9		
Montia cordifolia													7	T				
Mimulus spp.													7	T				
Arnica latifolia	11	T					15	T			16	1	50	2	53	4	57	2
Veratrum viride							8	2	25	T	5	T	29	1	28	1	29	T
Nothochelone nemorosa			8	T			4	T							9	T	57	T
Lilium columbianum	11	T													9	T	43	T
Saxifraga spp.													7	7	3	T		
Mertensia spp.													21	T			14	T
Valeriana sitchensis							4	1			21	2	43	3	69	5	86	3
Erythronium montanum													7	1	28	5		
Corallorhiza mertensiana															3	T		
Lupinus latifolius															6	1		
Caltha biflora															3	T		
Luzula glabrata															9	1		
Delphinium spp.															3	T		
Cicuta douglasia													7	2			14	T
Lathyrus spp.															3	T		
Thalictrum spp.															3	T		
Ligusticum grayi															9	1		
Polemonium pulcherrimum													7	T	6	1	29	T
Aquilegia formosa															3	T	14	T
Senecio triangularis																	14	T
Average total shrub cover[3]	57		22		10		36		89		36		35		12		11	
Average total herb cover[4]	56		59		30		117		121		79		93		78		57	

[1]Community type names and numbers correspond with those in Table 1.
[2]Constancy (Con) is the percent occurrence of a species in the plots assigned to each forest type. Characteristic cover (Cov) is the average cover of a species computed by averaging over only those plots where it occurs. Values are rounded to nearest percent. Values less than 0.5% are denoted by 'T'.
[3]Average total shrub cover is computed by summing the shrub cover on each plot, then averaging those totals over all plots in a type.
[4]Average total herb cover is computed by summing the herb cover on each plot, then averaging those totals over all plots in a type.

***Tsuga heterophylla/Achlys triphylla* Association**

The *Tsuga heterophylla/Achlys triphylla* Association (TSHE/ACTR) is confined to low elevations on the east side of the Park. Most of our sample plots are located in the Ohanapecosh Valley, but the type also occurs in the White River drainage. Elevation of the plots ranges from 550 to 1080 m (1,815 to 2,900 ft) and nearly all plots are on gentle, lower slopes or sites on valley bottoms. Soils are consistently weakly developed podzols in tephra deposits (typically tephra W over C).

Mature forests are quite dense and strongly dominated by *Pseudotsuga menziesii* (Fig. 12 and Table 3), with *Tsuga heterophylla* and *Thuja plicata* as major associates, although this characterization probably reflects the preponderance of samples in the 250-year-old stands of the lower Ohanapecosh Valley. *Abies amabilis* is a minor species. *Tsuga heterophylla* invariably makes up most of the seedlings and saplings.

Three-layered understories are typical of TSHE/ACTR Association (Table 4). A tall shrub layer of *Berberis nervosa, Vaccinium parvifolium, V. alaskaense, Rosa gymnocarpa*, and *Gaultheria shallon* provide a total average shrub cover of 57 percent. The well-developed herb layer (see Fig. 12) (average cover 56 percent) is rich in species. *Achlys triphylla, Viola sempervirens, Linnaea borealis, Cornus canadensis*, and *Tiarella unifoliata* dominate. *Rubus ursinus, Smilacina stellata, Trillium ovatum, Chimaphila umbellata, Disporum oreganum, Rubus lasiococcus, R. nivalis, R. pedatus, Pteridium aquilinum*, and *Polystichum munitum* are other common herbaceous species.

No young stands were sampled on this habitat. *Pseudotsuga* is obviously a major dominant in young stands. We suspect that some of the stands assigned to the *Pseudotsuga menziesii/Viola sempervirens* community type are representative of early stages of forest development of the TSHE/ACTR type.

The dense, middle-aged stands of *Pseudotsuga* are an outstanding feature of this forest type. It is not particularly resilient under heavy use because most understory plants are quite susceptible to trampling and soil compaction; much of Ohanapecosh Campground occurs in this habitat type.

The TSHE/ACTR type is related geographically and floristically to the *Berberis nervosa* phase of the *Abies amabilis/Vaccinium alaskaense* and, to a lesser degree, the *Tsuga heterophylla/Gaultheria shallon* and *Abies amabilis/Berberis nervosa* associations. The low elevation and sparsity of *Abies amabilis* distinguishes TSHE/ACTR from the *Abies amabilis* Series. The rich herb cover and low cover of *Gaultheria* distinguish TSHE/ACTR from *Tsuga heterophylla/Gaultheria shallon*.

Comparable forest types have not been described elsewhere in the Cascade and Coast Ranges. Indeed, the geographic limitation of TSHE/

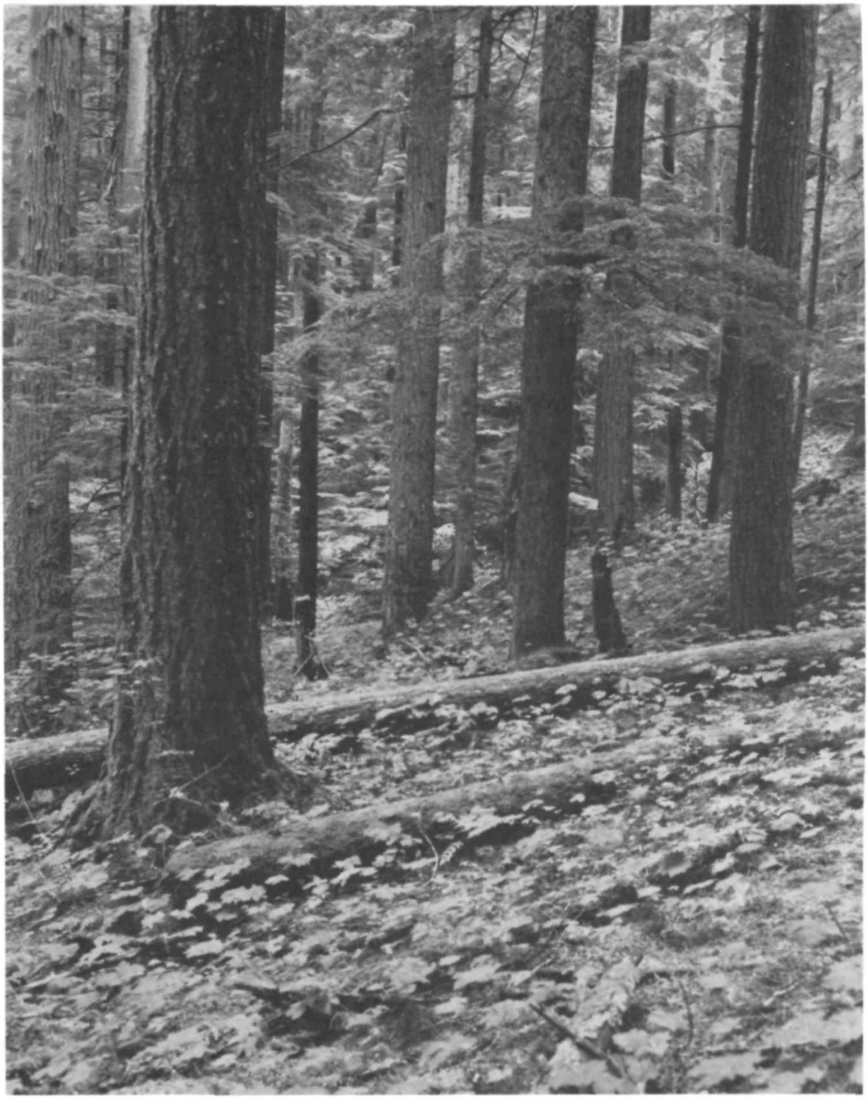

Figure 12. Mature 250-year-old *Pseudotsuga menziesii* forest in *Tsuga heterophylla/Achlys triphylla* habitat type; the herbaceous understory is unusually dense in this stand located near the Ohanapecosh Ranger Station.

ACTR type in the Park and the occurrence of most plots in a 250-year-old age class raise questions as to its validity as an association. Similar stands on the eastern slopes of the Cascade Range indicate that it is, at least, a widespread forest community if not climax type. The TSHE/

ACTR is similar to the *Tsuga heterophylla/Clintonia uniflora* Association of the northern Rocky Mountains (Daubenmire and Daubenmire 1968, Pfister et al. 1977) and to Franklin's (1966) *Abies amabilis/Achlys triphylla* Association of the Mount Adams region.

***Tsuga heterophylla/Polystichum munitum* Association**

The *Tsuga heterophylla/Polystichum munitum* Association (TSHE/POMU) and its *Abies amabilis* phase is a moist hillslope association confined to the western third of the Park where precipitation is higher. The typical TSHE/POMU type is found at elevations up to about 850 m (2,800 ft) in the Carbon, Mowich, Puyallup, and Nisqually drainages. It generally occupies moderate to steep lower slopes or sloping benches with southerly aspects, although three plots were on flat valley floors. Soils are developed in alluvium, colluvium, lahar, and tephra deposits and are frequently stony.

Mature stands in the TSHE/POMU type often have high densities of large trees (Fig. 13 and Table 3). *Pseudotsuga menziesii, Tsuga heterophylla*, and *Thuja plicata* are essentially the only species present except for a scattering of small *Abies amabilis*. Tree reproduction is over 90 percent *Tsuga heterophylla*, assuring it of climax status. *Thuja* reproduction is usually present but only in small numbers.

The understories of stands belonging to the TSHE/POMU Association are moderately developed with cumulative shrub cover of 22 percent and herb cover of 59 percent in the *Tsuga heterophylla* phase (Table 4). *Berberis nervosa* is the major shrub with *Acer circinatum* second. *Polystichum munitum* is the conspicuous dominant and major understory herb (see Fig. 13). Typical associated herbs are *Tiarella unifoliata, Gymnocarpium dryopteris, Achlys triphylla, Viola sempervirens*, and *Trillium ovatum*. *Taxus brevifolia* occurs in about half the plots of this forest type and averages 3 percent cover (but may be as high as 25 percent).

The *Abies amabilis* phase of this association can be weakly differentiated by the increased importance of the fir in regeneration and pole densities (Table 3). In the understory, the fern *Blechnum spicant* may dominate the herb assemblage or be codominant with *Polystichum munitum* (Table 4). There are no consistent site differences between plots of the *Abies amabilis* phase and those of the more typical *Tsuga heterophylla* phase, although the 10 plots of the former averaged about 106 m (350 ft) higher in elevation than the 12 plots of the latter.

No young stands were sampled on this TSHE/POMU habitat type. We suspect that brushfields would develop early in succession following a disturbance, followed by either stands of conifers (*Tsuga, Pseudotsuga*, and *Thuja*) or hardwoods (*Alnus rubra*). Perhaps the *Pseudotsuga menziesii/Polystichum munitum* and *Alnus rubra/Poly-*

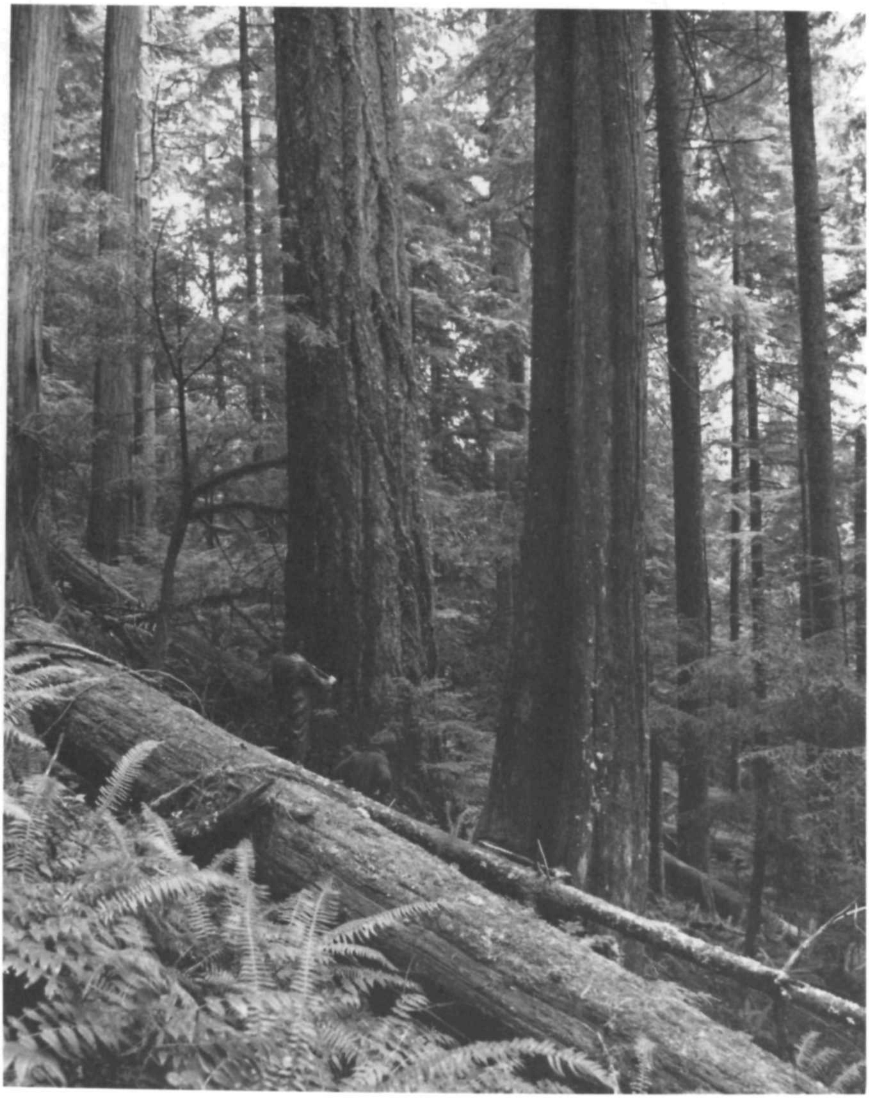

Figure 13. High densities of large trees are characteristic of mature stands in the *Tsuga heterophylla/Polystichum munitum* habitat type. *Pseudotsuga menziesii* and *Thuja plicata* are visible in this stand along the Chenuis Falls trail.

stichum munitum community types of del Moral and Long (1977) suggest the structure and floristics of young stands in the Park.

The TSHE/POMU is a very limited type in the Park. Its outstanding features include the fine stands of large old-growth *Pseudotsuga men-*

ziesii, which have very high biomasses. We suspect the TSHE/POMU habitat type is the most productive in the Park since it occupies low elevation, well watered sites with warm southerly aspects. Similar forest communities are common on both the Snoqualmie (Henderson and Peter 1981) and Gifford Pinchot (Topik et al. 1985) National Forests.

***Tsuga heterophylla/Oplopanax horridum* Association**

The luxuriant and often massive forests of the *Tsuga heterophylla/ Oplopanax horridum* Association (TSHE/OPHO) occur in all the major valleys of the Park. This association occupies wet benches, terraces, and lower slopes at low elevations. TSHE/OPHO sites extend to about 690 m (2,280 ft) in the Carbon River drainage and 970 m (3,200 ft) in the Nisqually-Ohanapecosh drainage. Alluvial soils lacking distinctive horizons are most common. Because most sample plots are on essentially flat ground, the aspects vary widely and are insignificant.

Mature forests are typically impressive, high volume stands of *Pseudotsuga menziesii, Thuja plicata*, and *Tsuga heterophylla* (Table 3). *Tsuga* is by far the most numerous, but large specimens of *Pseudotsuga* and *Thuja* contribute disproportionately to the basal area. *Picea sitchensis* is found in this association near the Carbon River entrance and in several plots in the Federation Forest State Park along the lower White River. *Abies grandis* occurs in the Nisqually and White River drainages. Scattered *Alnus rubra* and *Populus trichocarpa* provide a minor hardwood component. *Tsuga heterophylla* dominates the reproduction with some *Thuja plicata* and *Abies amabilis* seedlings and saplings (Table 3). There are many stands where reproduction of any tree species is rare, possibly due to the dense vegetative competition.

Understories in the TSHE/OPHO Association have luxuriant herbaceous layers (summed, their average cover is 116 percent) (Fig. 14) and shrub layers that vary from essentially absent to very dense (average cover 35 percent) (Table 4). Major shrub species are *Acer circinatum* and *Oplopanax horridum*, but their cover ranges from a trace up to 90 and 40 percent, respectively. Herb dominants include *Gymnocarpium dryopteris, Achlys triphylla, Tiarella unifoliata, Polystichum munitum, Athyrium filix-femina, Galium triflorum*, and *Smilacina stellata*. Several other distinctive species occasionally occur in this association and some, such as *Oxalis oregana*, can have substantial coverage; their presence is low, however. In fact, none of the dominant herbs are present in all stands (Table 4). Substantial shifts in herb dominants take place between stands, and considerable patchiness is often present within a stand. For example, coverage of *Gymnocarpium dryopteris, Oxalis oregana*, and *Achlys triphylla* in different plots of TSHE/OPHO Association range from zero to 80, 80, and 60 percent, respectively.

Figure 14. Luxuriant herbaceous understories are typical of forests comprising the *Tsuga heterophylla/Oplopanax horridum* habitat type, although substantial shifts in the herb dominants take place within and between stands.

Few young stands were sampled in this habitat type. Several of these were grouped in the *Alnus rubra/Rubus spectabilis* community type which appears to be a major successional forest on the TSHE/OPHO habitat type. Young conifer forests, typically composed of *Tsuga heterophylla, Pseudotsuga menziesii, Thuja plicata*, and *Abies grandis*, can also be expected following disturbances, along with *Populus trichocarpa*, provided they can get established before the *Alnus*.

The TSHE/OPHO Association characterizes one of the habitats that supports the massive valley forests encountered by visitors entering the Park's entrances. The rich understory provides diversity as well as forage for deer and especially for elk (*Cervus elaphus*). Ponds, seeps, and streams associated with this habitat make it a prime site for amphibians. The sometimes wet soils, high water tables, and above average windthrow are considerations when planning physical developments in this habitat type.

The TSHE/OPHO Association may border or form ecotones with a variety of *Tsuga heterophylla* and *Abies amabilis* forest types at lower

elevations. The most common contact is probably with the slightly drier TSHE/POMU Association in the western half and the TSHE/ACTR Association in the eastern half of the Park.

Park associations most closely related to the TSHE/OPHO are *Abies amabilis/Oplopanax horridum*, TSHE/POMU, and TSHE/ACTR associations. The TSHE/OPHO grades into the *Abies amabilis/Oplopanax horridum* with increasing elevation and differs mainly in the abundance of *Abies amabilis*. The TSHE/POMU Association is generally found on slopes and contains neither as rich an herbaceous cover nor diversity of species as does TSHE/OPHO. The TSHE/ACTR occupies substantially drier uplands and is much poorer in species than the TSHE/OPHO Association.

Communities related to TSHE/OPHO Association have been reported from several other locales throughout the Pacific Northwest. It is closely related to the Western Hemlock/Devil's Club/Swordfern Association on the Gifford Pinchot National Forest (Topik et al. 1985). Some stands of *Thuja plicata* found in the valley bottoms of North Cascades National Park are of this habitat type.[2] Comparable stands occur in coastal British Columbia (Krajina 1965). The *Thuja plicata/Oplopanax horridum* habitat type of northern Idaho (Daubenmire and Daubenmire 1968) and western Montana (Pfister et al. 1977) also appears to be comparable.

Alnus rubra/Rubus spectabilis Community Type

The *Alnus rubra/Rubus spectabilis* community type (ALRU/RUSP) identifies the seral *Alnus rubra* stands that develop on the TSHE/OPHO, low elevation *Abies amabilis/Oplopanax horridum*, and perhaps, TSHE/POMU habitat types following disturbance. The ALRU/RUSP community type can occur in any of the Park's valleys, but our sampled stands were in the Cowlitz and Nisqually River drainages. Range in elevation is up to at least 810 m (2,650 ft). Flat or gently sloping benches on valley bottoms and terraces with alluvial soils are typical.

Stands of the ALRU/RUSP type are, by definition, dominated by *Alnus rubra* (Fig. 15 and Table 3). Conifer associates may be absent, few, or codominant—depending mostly on stand history. Associates can include *Tsuga heterophylla, Thuja plicata, Pseudotsuga menziesii*, and *Abies amabilis*. Tree reproduction is typically absent or, at best, sparse; it often consists of seedling or sapling *Tsuga* or *Thuja* which were overtopped by *Alnus* early in the stand's history but have per-

[2]Unpublished report, "Phytosociological reconnaissance of western redcedar stands in four valleys of the North Cascades Park Complex," by Joseph W. Miller and Margaret M. Miller, 50 p., Dec. 1970. On file at Forestry Sciences Laboratory, Corvallis, Oregon.

Figure 15. The *Alnus rubra/Rubus spectabilis* community type is a seral community occurring on the *Tsuga heterophylla/Oplopanax horridum* and *Abies amabilis/Oplopanax horridum* habitat types; *Alnus rubra* dominates the tree layer, and there is a dense shrubby understory which is a favorite habitat for elk. In this stand along Tahoma Creek, *Oplopanax horridum* is conspicuous in the understory.

sisted. The absence of substantial tree reproduction by any species have led some ecologists to hypothesize that such stands turn into shrubfields of *Rubus spectabilis* as the short-lived *Alnus* dies out (Franklin and Dyrness 1973).

The understory in ALRU/RUSP stands has luxuriant shrub and herb layers (Table 4). *Rubus spectabilis* is the major shrub, although many others such as *Oplopanax horridum*, *Sambucus*, *Rubus parviflorus*, and *Ribes bracteosum* may be present in substantial amounts. Herbaceous cover is always high and highly varied in composition; typical important species include *Athyrium filix-femina*, *Achlys triphylla*, *Circaea alpinum*, *Tiarella unifoliata*, *Pteridium aquilinum*, *Gymnocarpium dryopteris*, *Viola glabella*, *Rubus lasiococcus*, and *Cinna latifolia*.

This community appears to be important wildlife habitat. Several stands were sampled in The Burn in the Cowlitz River drainage (where it is most extensive) and all were being heavily used by elk. Such communities are prime habitat for rodents such as mountain beaver.

Communities similar to the ALRU/RUSP are widespread on cutover and burned-over forest lands in western Washington and Oregon (Franklin and Dyrness 1973, Henderson 1978). The successional development of these stands is not understood, although it appears that both shrubfields and conifer stands are alternatives, depending on circumstances. In western Oregon, Henderson (1978) found little evidence of conifers replacing 64 years of alder dominance despite a declining crown closure in the alder overstory as the sere progressed. The ALRU/RUSP community does deter conifer development. Extensive examples of the type are seen on cutover lands along all the highways approaching the Park from the west, including the Mowich Lake road. Many such stands on private lands are being converted to conifer forest by felling, burning, and planting.

***Abies amabilis/Oplopanax horridum* Association**

The primary TSHE/OPHO Association on wet valley bottom benches, terraces, and lower slopes gradually changes with higher elevations to the *Abies amabilis/Oplopanax horridum* Association (ABAM/OPHO). Stands are still richly vegetated but have *Abies amabilis* as a regular component. The overall elevational range of the 33 study plots is from 650 to 1190 m (2,145 to 3,900 ft) for stands on the valley bottoms and 810 to 1460 m (2,670 to 4,820 ft) for those on mountain slopes. The transitional elevation from TSHE/OPHO to ABAM/OPHO is lowest in the Carbon River drainage (about 650 m or 2,150 ft), intermediate in the Nisqually and Ohanapecosh drainages (around 750 m or 2,500 ft), and highest in the White River drainage (around 900 m or 3,000 ft). Stands of the ABAM/OPHO Association on valley bottoms occupy gentle (0 to 20 percent slope) terraces and benches with varying aspects. High-elevation stands are most commonly found on steep (23 to 75 percent), lower slopes with northerly aspects but may occur on south aspects (especially near the upper limits of the habitat type) and on midslopes or even upper slopes. Soils in valley bottom stands are generally developing on alluvium and lahar surfaces. They vary widely in morphology from deep, nondescript layers of gray sand to distinctive podzolic profiles. Soils of slope stands have stony colluvial (most common), alluvial, and tephra parent materials (Hobson 1976).

Mature forests of valley bottoms typically are impressive with massive specimens of *Thuja plicata* and *Pseudotsuga menziesii* mingled with more numerous *Abies amabilis* and *Tsuga heterophylla* (Fig. 16 and Table 3). Other species encountered in minor quantities are *Picea engelmannii*, *Abies procera*, and *Chamaecyparis nootkatensis*. Taking all stands into consideration, seedlings of *Abies amabilis* and *Tsuga heterophylla* are about equally abundant whereas *Abies amabilis* has clear superiority in saplings. In fact, there is wide variation in both the

Figure 16. This stand in the *Abies amabilis/Oplopanax horridum* habitat type has a very dense layer of *Oplopanax horridum*; a well-developed herb layer is also present. Along lower Chinook Creek.

total amount and species composition of tree reproduction which is at least partially related to the severe competition from shrubs and herbs.

Abies amabilis dominates mature stands on slopes with *Tsuga heterophylla* as the major associate. Large specimens of *Thuja plicata*, *Abies procera*, or *Picea engelmannii* are occasionally encountered. One stand at a very high elevation contained considerable *Tsuga mertensiana*. Reproduction in stands of ABAM/OPHO on slopes is more uniformly abundant than on the valley bottom. *Abies amabilis* dominates although *Tsuga heterophylla* is still important, suggesting it has at least a minor climax role.

The understory of the ABAM/OPHO Association is always luxuriant on valley bottoms and, as with the TSHE/OPHO, is rich in species (Table 4). The composition and structure vary widely, however. Some stands have a continuous carpet of herbs with essentially no shrub layer, whereas others have a dense tangle of *Oplopanax horridum*, *Rubus spectabilis*, and *Vaccinium* spp. (see Fig. 16). The shrub layer averages 32 percent in valley bottom stands with *Oplopanax*, *Vaccinium*

alaskaense, Vaccinium ovalifolium, and *Rubus spectabilis* the most important species. The dense herb layer (average cover 79 percent) has *Gymnocarpium dryopteris, Achlys triphylla, Tiarella unifoliata, Rubus pedatus, Streptopus roseus*, and *Athyrium filix-femina* as important species. There is, however, substantial patchiness within stands and shifts in the herb dominants between stands; for example, *Gymnocarpium* varies from 0 to 90 percent cover.

The understory of ABAM/OPHO stands on slopes is similar to that of valley bottom stands, with 35 percent shrub and 93 percent herb covers. *Ribes lacustre* has more importance on slopes than on valley bottoms. *Acer circinatum* is not common, but, as on the valley bottom, may have considerable coverage when present. *Tiarella unifoliata* increases in importance, essentially replacing *Tiarella trifoliata*. More typical mountain slope species, such as *Rubus lasiococcus* and *Viola glabella*, are also more common; but *Gymnocarpium dryopteris, Achlys triphylla, Streptopus roseus*, and *Athyrium filix-femina* remain important.

Few young stands were sampled on the ABAM/OPHO Habitat Type. It appears that valley bottom sites can develop stands partially or wholly dominated by *Alnus rubra* following disturbance, at least at the lowest elevations. These forests belong to the ALRU/RUSP community type discussed earlier. Young conifer stands of highly variable composition can also develop immediately following disturbance. These are as likely to be dominated by shade-tolerant species such as *Abies amabilis* and especially *Tsuga heterophylla* as they are by so-called pioneer species such as *Pseudotsuga menziesii* or *Abies procera*. Early stages in succession will generally have dense shrub covers of *Rubus spectabilis, R. parviflorus, Sambucus*, and *Salix* spp.

The special features of the ABAM/OPHO Association are much the same as those of the TSHE/OPHO. It is a rich and productive environment where the most massive forests and largest individual trees in the Park are encountered. Most of the very old stands (800 years or more in age) known in the Park belong to the ABAM/OPHO Association. It provides important wildlife habitat and is heavily used by elk except when covered by snow.

The ABAM/OPHO Association usually has ecotones to *Abies amabilis/Tiarella unifoliata* and *Abies amabilis/Vaccinium alaskaense* types. One common pattern involves islands of the *Abies amabilis/Tiarella unifoliata* Association on raised ground within a matrix of ABAM/OPHO on lower, more poorly drained microrelief. On steeper slopes, ABAM/OPHO forests occur along drainages otherwise within the drier *Abies amabilis/Tiarella unifoliata* Association. Similar mosaics controlled by microrelief may occur between ABAM/OPHO and drier associations such as *Abies amabilis/Vaccinium alaskaense* and *Abies amabilis/Gaultheria shallon*. Within any of these drier forest hab-

itat types, inclusions of ABAM/OPHO forests can be found on wet branches, seeps, or drainages.

The ABAM/OPHO Association is environmentally and floristically related to both the TSHE/OPHO and *Abies amabilis/Tiarella unifoliata* Associations. Both *Oplopanax horridum* types are arbitrary divisions of a floristic continuum that extends from lower valleys and drainages to midelevation valleys and wet slopes. The general absence of *Oplopanax horridum* and several herb species on somewhat drier (and probably warmer) sites serves to distinguish *Abies amabilis/Tiarella unifoliata* from the ABAM/OPHO Association.

Communities comparable to our ABAM/OPHO type have been described from many other locales in the Cascade Range, British Columbia, and the northern Rocky Mountains. Franklin's (1966) *Abies amabilis/Oplopanax horridum* association in the southern Washington Cascade Range is essentially identical, as is that described by Brockway et al. (1983). We have sampled a comparable community in the Cedar River drainage, although a *Tsuga heterophylla/Vaccinium alaskaense* community is the closest approximation reported by del Moral and Long (1977). Closely related communities are common in the North Cascades and in intervening portions of the Mt. Baker-Snoqualmie National Forest. A *Chamaecyparis nootkatensis/Oplopanax horridum* association appears to be the closest approximation in the Oregon Cascade Range (Dyrness et al. 1974). The closest relative in the northern Rocky Mountains would appear to be the *Abies lasiocarpa/Oplopanax horridum* Association (Pfister et al. 1977).

Abies amabilis/Tiarella unifoliata Association

The *Abies amabilis/Tiarella unifoliata* Association (ABAM/TIUN) is herb-rich and occupies mesic mountain slopes at middle elevations. It occurs throughout the Park but is most common in the White and Ohanapecosh River drainages. The elevational range of our 39 sample plots is from 830 to 1490 m (2,740 to 4,920 ft). In the White, Ohanapecosh and Nisqually River drainages, the association often occupies moderate to steep, southerly exposed slopes, sloping benches, and draws—warm but well-watered environments. In the Mowich, Carbon, and North Puyallup River drainages, ABAM/TIUN sites were encountered mostly on steep north-facing slopes above 1200 m (4,000 ft). Despite the contrast in aspect, we found no consistent floristic differences in communities in the two geographic areas; hence we treat them as a single association. Soils are developed in either tephra deposits or colluvium; profiles are deep and well drained, with no evidence of iron-pan development.

Mature forests in the ABAM/TIUN Association are dominated by *Abies amabilis*, *Abies procera*, and *Tsuga heterophylla* (Table 3). *Pseudotsuga menziesii* is an important associate and can dominate some

young stands. There are substantial shifts between the three leading species with stand age. *Abies procera* is very important in stands up to 400 years of age; we recognized an *Abies procera/Tiarella unifoliata* community type because of the extent of these distinctive stands. *Abies procera* is mostly absent from stands older than 400 years which are dominated by *Abies amabilis* and *Tsuga heterophylla* instead. About 90 percent of tree reproduction is *Abies amabilis* in these old stands; saplings are *Abies amabilis* (77 percent), *Tsuga heterophylla* (20 percent), and occasional *Chamaecyparis nootkatensis* (3 percent).

The understory has weak shrub and dense herb layers (average cover 12 and 78 percent, respectively) (Table 4). The major shrubs are *Acer circinatum* and *Vaccinium membranaceum*, but *Acer circinatum* is present in less than half the stands; small amounts of *Vaccinium ovalifolium* are typically present. Some of the more important herbs are *Tiarella unifoliata, Achlys triphylla, Streptopus roseus, Valeriana sitchensis, Rubus lasiococcus, Arnica latifolia, Clintonia uniflora*, and *Smilacina stellata. Gymnocarpium dryopteris* has high coverage in a few stands but is generally absent; the absence or low values for *Gymnocarpium, Oplopanax horridum, Rubus spectabilis*, and *Athyrium filix-femina* distinguish this association from the closely related slope variant of the ABAM/OPHO type.

We have already commented on the tendency for *Abies procera* or *Pseudotsuga menziesii* or both to dominate young stands. Some of the successional shifts in understory dominants have been reported by Moir et al. (1979).

One of the unique and distinctive features of the ABAM/TIUN Habitat Type is its fine stands of *Abies procera* (Fig. 17). They are notable on the slopes of Sunrise Ridge (see frontispiece), around Nahunta Falls below the Nisqually River Bridge (easily viewed from the Paradise Valley road east of the river), and on the north side of the Mowich River above Mowich Lake road. It is a productive habitat and capable of rapid recovery following disturbance. Visitors find it attractive for its open, yet luxuriant understories and relatively warm exposures.

The ABAM/TIUN Association is closely related to the *Abies amabilis/Rubus lasiococcus* and slope phases of the ABAM/OPHO types. ABAM/OPHO often occurs as a stringer and as patches on wetter sites within a matrix of ABAM/TIUN habitats. The ABAM/TIUN Association grades into *Abies amabilis/Rubus lasiococcus* with elevation, both types tending to occupy southerly mountain slopes. On Sunrise Ridge (frontispiece), the contact between the two associations is quite sharply defined by the shift in dominance from *Abies procera* to *Abies lasiocarpa*. Elsewhere, however, the *Erythronium montanum* phase of the *Abies amabilis/Rubus lasiococcus* Association can be difficult to distinguish from ABAM/TIUN but is generally poorer in herb cover and species.

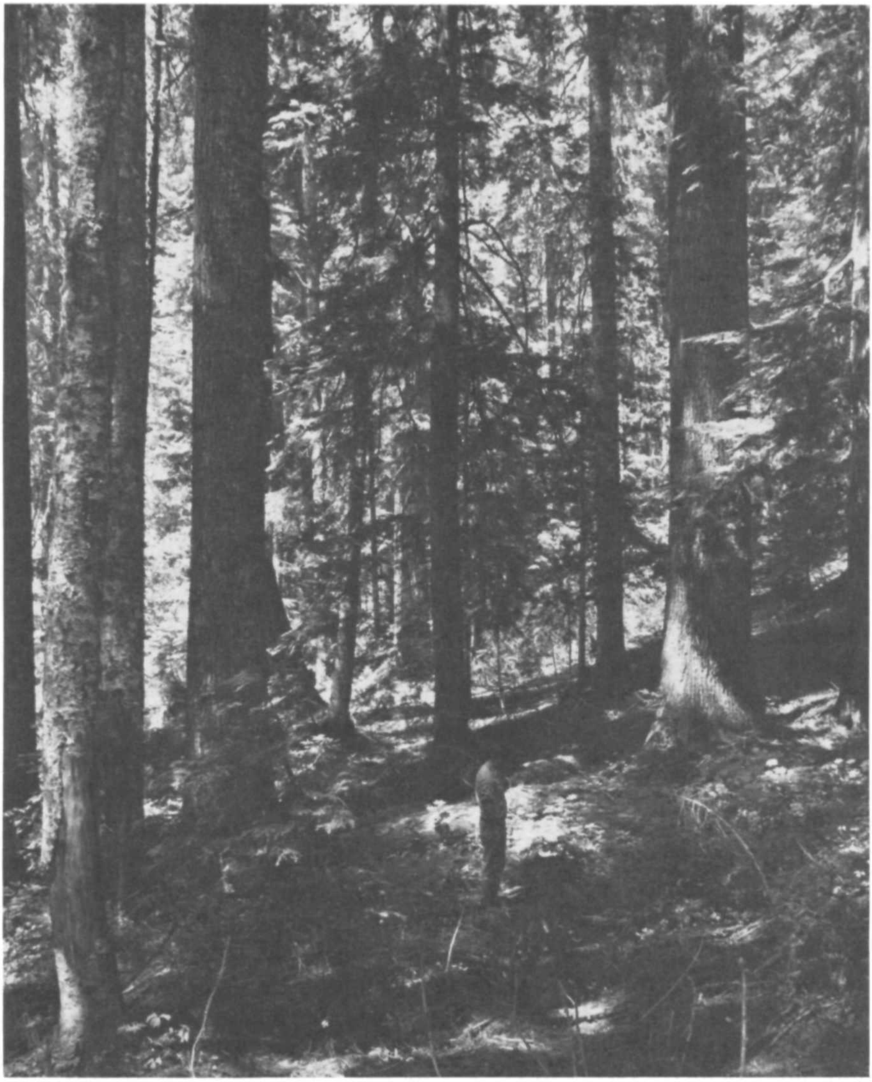

Figure 17. Outstanding examples of *Abies procera* are common on *Abies amabilis/Tiarella unifoliata* habitat type.

Our ABAM/TIUN Association is one element in a series of shrub-poor, herb-dominated *Abies amabilis* types recognized in the southern Washington and Oregon Cascade Range. Franklin's (1966) *Abies amabilis/Streptopus curvipes* and *Abies amabilis/Tiarella unifoliata* associations are closely related to our type at the wet (northwestern) and dry (northeastern) ends, respectively, of the moisture and floristic

gradient that it spans in the Park. The Pacific Silver Fir/Coolwort Foamflower Association described for the Gifford Pinchot National Forest (Brockway et al. 1983) is very similar but is slightly poorer in herbs and richer in shrub cover than our association. The *Abies amabilis/Streptopus roseus* Association of Henderson and Peter (1981) is also similar. In Oregon, *Abies amabilis/Tiarella unifoliata* and *Abies amabilis/Achlys triphylla* associations (Dyrness et al. 1974) appear to divide an environmental and floristic gradient on sites similar to our *Abies amabilis/Tiarella unifoliata* type. In both southern Washington and Oregon, the ABAM/TIUN habitat is where *Abies procera* attains superior growth and greatest stocking densities. The *Abies lasiocarpa/Clintonia uniflora* Association of western Montana (Pfister et al. 1977) and *Abies lasiocarpa/Pachystima myrsinites* Association of northern Idaho (Daubenmire and Daubenmire 1968) are probably the closest northern Rocky Mountain relatives to our ABAM/TIUN.

Modal Forest Ecosystems

Modal forests occupy habitats that lack extreme environmental conditions, i.e., sites excessively wet, dry, cold, or hot. This is, of course, a relative matter considered in the context of the study area. At Mount Rainier the center of the environmental field is occupied by a single, very widespread association, the *Abies amabilis/Vaccinium alaskaense* (Fig. 11). Characteristics of the tree species are presented in Table 5 and data on the shrub and herb constituents in Table 6.

Abies amabilis/Vaccinium alaskaense Association

The *Abies amabilis/Vaccinium alaskaense* Association (ABAM/VAAL) is the most extensive of the types found in Mount Rainier National Park. In fact, the mature forests of *Tsuga heterophylla, Pseudotsuga menziesii*, and *Abies amabilis* and their associated shrubs and herbs (Fig. 18; see also Plate 1) characterize not only the association but the forests of Mount Rainier as a whole. This association occupies environments lacking extremes of temperature and moisture (see Fig. 11). Nevertheless, the type is widespread—about 20 percent of all our plots are ABAM/VAAL and the percentage would probably be higher in a random sample. The type also varies substantially, necessitating recognition of several phases—*Rubus pedatus, Chamaecyparis nootkatensis*, and *Berberis nervosa*. Discussion of these phases follows that of the typical *Vaccinium alaskaense* phase of the ABAM/VAAL Association.

Vaccinium alaskaense Phase—The *Vaccinium alaskaense* phase of the ABAM/VAAL Association generally ranges from 900 to 1330 m (3,000 to 4,390 ft) in elevation, except in the Ohanapecosh drainage where it extends down to 660 m (2,180 ft). It occurs on all aspects on

Figure 18. Mature forests of *Abies amabilis, Tsuga heterophylla*, and *Pseudotsuga menziesii* characterize the very widespread *Abies amabilis/Vaccinium alaskaense* habitat type. This type occupies modal environments, can be considered the climatic climax of the *Abies amabilis* zone, and is the forest archetype for Mount Rainier National Park.

middle and lower slopes and well-drained benches and valley bottom sites; the slopes vary from gentle to moderate (less than 50 percent). The deep, well-drained soils are most commonly podzolic and developed in tephra deposits (for example, see the soil profile for Fryingpan Creek in Chapter 2; see also Fig. 5), although they may also be in alluvial, colluvial, or even laharic parent materials.

Mature forests on the *Vaccinium alaskaense* phase of this Association are composed of *Tsuga heterophylla, Abies amabilis*, and *Pseudotsuga menziesii*, the latter few in number but large in size (Table 5). *Thuja plicata* is the only other significant species. *Abies amabilis* and *Tsuga heterophylla* dominate the tree reproduction at an average species ratio of 2:1. The *Tsuga heterophylla* seedlings and saplings have a tendency to decrease with elevation; even at low elevations, however, these seedlings rarely exceed those of *Abies amabilis* in number or vigor, and they are essentially confined to raised seedbeds (rotten logs, stumps, and rootwads) (Fig. 19).

Figure 19. *Tsuga heterophylla* reproduction in the *Abies amabilis/Vaccinium alaskaense* habitat type is essentially confined to rotten logs and other raised seedbeds; this is true in most other associations as well.

Understories have well-developed shrub and weak herb layers (average cover 52 and 17 percent, respectively) (Table 6). *Vaccinium alaskaense* is by far the most important shrub, but *Vaccinium ovalifolium, V. membranaceum, V. parvifolium*, and *Menziesia ferruginea* are typically present and can contribute substantial cover in individual stands. The herb layer is composed of a set of evergreen species, each occurring in the majority (but not all) of the plots: *Linnaea borealis, Cornus canadensis, Clintonia uniflora, Rubus lasiococcus, R. pedatus, Chimaphila umbellata, C. menziesii, Pyrola secunda*, and *Goodyera oblongifolia*.

A few young stands were sampled. *Pseudotsuga menziesii* can be a dominant along with *Tsuga heterophylla* and, to a lesser extent, *Abies amabilis*. The role of *Abies procera* is unclear. Few of our stands included *Abies procera* but this may reflect the fact that most stands were over 400 years old, by which time *Abies procera* is largely eliminated. Some young stands of the *Vaccinium alaskaense* phase may be included within the *Pseudotsuga menziesii/Viola sempervirens* community type.

Berberis nervosa Phase—The *Berberis nervosa* phase of the ABAM/VAAL Association was sampled at elevations from 630 to 1220 m (2,080 to 4,080 ft). Plots are mostly on lower slopes or valley bottoms of southerly exposure. The soils are similar to those of the *Vaccinium alaskaense* phase, namely deep, well-drained soils of tephra and colluvial deposits (Hobson 1976).

Pseudotsuga menziesii and *Tsuga heterophylla* are codominants of the overstory canopy; *Thuja plicata* and, less frequently, *Abies amabilis* are minor overstory species (Table 5). As within the *Vaccinium alaskaense* phase, tree reproduction continues to be dominated by *Abies amabilis* in the *Berberis nervosa* phase. Seedling densities of *Abies amabilis*, compared to the second ranked *Tsuga heterophylla*, have an average ratio of 2:1. *Thuja plicata* seedlings are also present in most plots but are of low density. The three tree species together account for 98 percent of seedling establishment.

Understories in the *Berberis nervosa* phase reflect an environment somewhat warmer and drier than that of the *Vaccinium alaskaense* phase (Table 6). *Vaccinium parvifolium* and *Berberis nervosa* join *Vaccinium alaskaense* as regular and important members of the shrub layer. *Taxus brevifolia* and *Acer circinatum* are present in about two-thirds of the plots and are considerably more important than in the *Vaccinium alaskaense* phase. *Vaccinium ovalifolium* and *Menziesia ferruginea* are, on the other hand, less important. Composition of the herb layer of the *Berberis nervosa* phase differs from the *Vaccinium alaskaense* phase in poorer representation of *Clintonia uniflora* and greater coverage of *Linnaea borealis*.

Rubus pedatus Phase—This phase of the ABAM/VAAL Association is mostly confined to the Carbon, Mowich, and North Puyallup River drainages. Our plots ranged in elevation from 840 to 1380 m (2,770 to 4,550 ft) and were generally of northerly exposures on lower to upper slopes and benches. Soils developed from deep tephra deposits often had strong iron pan development. These site characteristics suggest that the *Rubus pedatus* phase represents the ABAM/VAAL type near the cooler and wetter portion of its range.

Tsuga heterophylla and *Abies amabilis* are almost the only trees present (Table 5). The latter strongly dominates tree reproduction with an average seedling ratio of 11:1 compared to *Tsuga heterophylla*. *Tsuga mertensiana* and *Chamaecyparis nootkatensis* are both very minor, each contributing only about one percent of the total seedling density.

Shrub dominants in order of importance are *Vaccinium alaskaense*, *V. ovalifolium*, *V. membranaceum*, and *Menziesia ferruginea* (Table 6). Collectively these provide an average cover of 43 percent. Warm-site shrubs such as *Acer circinatum* and *Berberis nervosa* are absent or

Table 5. Average tree density (stems per hectare) for the modal forest types by species and stem-diameter class, Mount Rainier National Park.

Type and species[1]	Con[2]	Basal area[3]	≤1[5] ≤1.4 m	≤1[5] >1.4 m	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	>12
			Stem-diameter class[4]													
Abies amabilis/Vaccinium alaskaense Association, *Vaccinium alaskaense* Phase																
Tsuga heterophylla	100	32.6	4,758	205	51	18	11	11	11	9	9	5	8	3	3	3
Abies amabilis	100	23.9	10,079	602	138	52	39	19	13	7	3	4	2			
Pseudotsuga menziesii	58	18.1	51		1	3		1	3	1	2	3	5	1	1	6
Thuja plicata	37	5.8	98	23	4	1	2	2	1	2	1	2				1
Chamaecyparis nootkatensis	23	1.7	23	6	4	1				1	2					
Tsuga mertensiana	14	1.1	5	1	2	2							1			
Abies procera	12	2.8											1		1	
Pinus monticola	9	0.3	5				1									
All species[6]		86.2	15,019	839	200	77	53	34	28	20	18	14	16	5	6	10
Abies amabilis/Vaccinium alaskaense Association, *Berberis nervosa* Phase																
Tsuga heterophylla	100	33.5	2,137	263	55	25	26	30	19	8	11	8	3	1	3	
Abies amabilis	100	11.9	4,642	449	81	51	26	14	8		1					
Pseudotsuga menziesii	84	30.4	11	6	7	14	8	4	15	5	6	1	1	3	2	9
Thuja plicata	74	7.0	326	60	13	11	7	5	5	4	1	2				
Chamaecyparis nootkatensis	21	0.0	105	15												
Abies procera	16	0.6		1			1			1						
Pinus monticola	11	0.0	32													
Tsuga mertensiana	5	0.0		2												
All species[6]		83.4	7,253	796	156	102	68	53	46	19	19	12	5	4	6	9
Abies amabilis/Vaccinium alaskaense Association, *Rubus pedatus* Phase																
Tsuga heterophylla	100	34.1	1,200	690	69	12	3	9	1	14	6	6	8	3	4	4
Abies amabilis	95	31.5	11,926	594	94	41	27	31	28	13	9	5	2			
Pseudotsuga menziesii	32	9.1		7						1		3			2	3
Tsuga mertensiana	32	0.1	126	8	4											
Abies procera	26	5.0		91						2	2	2	1		1	
Chamaecyparis nootkatensis	26	3.2	137	1	1				1	1	1		1			1
Thuja plicata	11	1.9	32			1	2	1		1					1	
All species[6]		84.9	13,421	1,391	169	54	33	41	30	33	18	17	13	3	9	7
Abies amabilis/Vaccinium alaskaense Association, *Chamaecyparis nootkatensis* Phase																
Tsuga heterophylla	100	29.7	1,333	123	22	34	18	19	37	11	8	11				
Chamaecyparis nootkatensis	100	18.9	1,967	149	33	25	22	17	13	14	4	4				
Abies amabilis	100	10.0	11,400	1,016	79	35	15	10	8							
Pseudotsuga menziesii	67	14.3								11	4	3		4	3	
Tsuga mertensiana	33	8.4	133	3		3	3	3	14	7		3				
All species[6]		81.2	14,833	1,290	134	98	58	50	72	43	16	22		4	3	

[1]Species are ordered within type by constancy.
[2]Constancy, expressed as percent of sample containing the species.
[3]Expressed as meters squared per hectare.
[4]Decimeters (dm) in diameter at breast height (1.4 m above the ground).
[5]The ≤1 dm diameter class is subdivided into two classes based on height.
[6]Column sums may not be exact due to rounding error.

Table 6. Constancy and characteristic cover of all shrub and herb taxa for the modal forest community types of Mount Rainier National Park.

	Community type[1]							
	7a.		7b. ABAM/VAAL		7c.		7d.	
Number of plots per type:	VAAL phase 43		BENE phase 19		RUPE phase 19		CHNO phase 6	
Taxa	Con	Cov[2]	Con	Cov	Con	Cov	Con	Cov
SHRUBS								
Sambucus spp.	2	T						
Acer glabrum	2	T						
Vaccinium scoparium	5	2						
Rosa gymnocarpa	14	T	26	3				
Rubus ursinus	21	T	42	1				
Symphoricarpos mollis	2	T	5	T				
Oplopanax horridum	14	T	5	4	11	T		
Chimaphila umbellata	63	1	95	4			50	1
Amelanchier alnifolia	2	T	11	1				
Taxus brevifolia	14	3	68	8				
Cornus canadensis	63	2	74	3	37	2	50	1
Rubus parviflorus	5	7	5	T	5	1		
Vaccinium parvifolium	65	2	100	8	42	2	50	4
Acer circinatum	26	12	63	9	5	T	33	1
Berberis nervosa	26	1	100	8	11	T	17	1
Gaultheria ovatifolia	30	3	63	2	5	T	50	2
Chimaphila menziesii	53	T	74	T	21	T	83	T
Rubus lasiococcus	74	2	74	1	63	2	67	T
Sorbus sitchensis	26	T	21	T	37	1		
Gaultheria shallon	5	1	47	T				
Vaccinium ovalifolium	84	11	37	4	74	14	100	9
Vaccinium alaskaense	100	32	95	13	95	30	100	33
Vaccinium membranaceum	88	3	79	2	79	4	100	6
Menziesia ferruginea	67	3	32	1	79	1	67	1
Pachistima myrsinites	12	T	32	1			33	T
Rubus pedatus	65	3	42	1	100	12	67	2
Vaccinium deliciosum			5	4				
Salix scouleriana			5	T				
Rubus spectabilis	7	T			16	1		
Corylus cornuta			5	T				
Ribes lacustre	5	1	5	T	5	T	17	T
Rhododendron albiflorum	9	2			26	1	17	8
Alnus sinuata	2	3					17	T
Ribes spp.					5	T		

Table 6. Continued

	Community type[1]							
	7a.		7b.		7c.		7d.	
	ABAM/VAAL							
Number of plots per type:	VAAL phase 43		BENE phase 19		RUPE phase 19		CHNO phase 6	
Taxa	Con	Cov[2]	Con	Cov	Con	Cov	Con	Cov
HERBS								
Lilium columbianum	2	T						
Pyrola picta	2	T						
Equisetum fluviatile	2	T						
Dryopteris austriaca	5	1						
Adenocaulon bicolor	5	T						
Osmorhiza spp.	2	T						
Lysichitum americanum	2	T						
Luzula parviflora	2	T						
Lupinus latifolius	2	T						
Adiantum pedatum	2	T						
Disporum hookeri	5	T	5	T				
Corallorhiza maculata	2	T	5	T				
Trifolium latifolium	2	T	5	T				
Monotropa uniflora	2	T	5	T				
Madia dissitiflora	12	T	11	T	5	T		
Pteridium aquilinum	9	1	11	1	5	3		
Pyrola uniflora	7	T	5	T	5	T		
Veratrum viride	5	T			5	T		
Valeriana sitchensis	5	T			5	T		
Lycopodium clavatum	12	1	11	T	11	1		
Achlys triphylla	53	2	58	2	32	2	33	T
Listera borealis	70	4	100	13	21	2	83	3
Trillium ovatum	42	T	47	T	42	T	17	T
Goodyera oblongifolia	56	T	74	T	11	T	100	T
Tiarella unifoliata	47	1	37	T	53	1	17	T
Smilacina stellata	23	1	21	T	21	T	17	T
Streptopus amplexifolius	5	T	11	T	5	T		
Viola sempervirens	26	T	37	4	16	T	33	T
Polystichum munitum	5	T	21	T	5	1		
Pyrola asarifolia	19	1	63	T	5	T	33	T
Athyrium filix-femina	12	T			21	T		
Clintonia uniflora	77	3	53	1	95	4	83	T
Corallorhiza spp.	37	T	84	T	37	T	50	T
Pyrola secunda	67	1	79	1	79	1	83	T
Lithospermum californicum	28	T	16	T	37	T	33	T

Table 6. Continued

	Community type[1]							
	7a.		7b.		7c.		7d.	
	ABAM/VAAL							
Number of plots per type:	VAAL phase 43		BENE phase 19		RUPE phase 19		CHNO phase 6	
Taxa	Con	Cov[2]	Con	Cov	Con	Cov	Con	Cov
Polemonium spp.			5	1				
Trautvetteria grandis	2	T			5	1		
Smilacina racemosa	2	T	5	T	5	T		
Pyrola virens			5	T				
Hemitomes congestum			5	T				
Cystopteris fragilis	2	T			5	T		
Allotropa virgata	7	T			16	T		
Thalictrum spp.			5	T				
Nothochelone nemorosa			5	T				
Listera cordata	28	T	26	T	47	1	33	T
Streptopus roseus	33	2	11	1	74	2	17	1
Gymnocarpium dryopteris	7	1			21	2		
Xerophyllus tenax	23	9	37	2	32	5	67	T
Blechnum spicant	21	2	11	T	53	2	33	T
Tiarella trifoliata	9	1	11	1	37	1		
Hieracium albiflorum	7	T	11	T	5	T	33	T
Streptopus streptopoides	9	T			53	2	17	T
Viola glabella	2	2	11	5	16	1	17	T
Hypopitys monotropa	2	T			21	T		
Epilobium angustifolium	2	T			11	T	17	T
Erythronium montanum	2	20			21	1	17	6
Corallorhiza mertensiana					5	T		
Mitella spp.					5	T		
Bromus vulgaris					5	T		
Arnica latifolia	2	T			11	T	33	T
Average total shrub cover[3]	52		45		45		54	
Average total herb cover[4]	17		25		28		8	

[1]Community type names and numbers correspond with those in Table 1.

[2]Constancy (Con) is the percent occurrence of a species in the plots assigned to each forest type. Characteristic cover (Cov) is the average cover of a species computed by averaging over only those plots where it occurs. Values are rounded to nearest percent. Values less than 0.5% are denoted by 'T'.

[3]Average total shrub cover is computed by summing the shrub cover on each plot, then averaging those totals over all plots in a type.

[4]Average total herb cover is computed by summing the herb cover on each plot, then averaging those totals over all plots in a type.

minor. In the herb layer, dominance by *Rubus pedatus* is one of the distinguishing features of this phase. Other herbaceous differences between the *Rubus pedatus* and *Vaccinium alaskaense* phases are the near disappearance of *Linnaea borealis* and *Cornus canadensis* from the *Rubus pedatus* phase, and the greater importance in this phase of *Clintonia uniflora* and *Streptopus roseus*. In addition, total herbaceous cover is greater, on the average (27 percent), in the *Rubus pedatus* phase than it is in the *Vaccinium alaskaense* phase.

The *Rubus pedatus* phase of the ABAM/VAAL has been interpreted in several ways during the development of our classification. It forms a bridge between the *Vaccinium alaskaense* of the ABAM/VAAL phase and the *Abies amabilis/Menziesia ferruginea* Association; the *Rubus pedatus* phase of ABAM/VAAL is closely related to *Abies amabilis/ Menziesia ferruginea* and intergrades with it. The phase is distinctive enough, however, that we gave it full status as a habitat type early in the study (Moir et al. 1979).

Chamaecyparis nootkatensis Phase—This phase of the ABAM/VAAL Association is based on six plots scattered in various sectors of the Park. Elevations range from 930 to 1360 m (3,070 to 4,490 ft). Most plots occurred on lower slopes of southerly to westerly aspect. Soils varied from a shallow, cobbly-skeletal profile on laharic substrate to more typical, deep, and well-drained tephra soils similar to those of the *Vaccinium alaskaense* phase.

A distinguishing feature of this phase is the importance of *Chamaecyparis nootkatensis* (Table 5). This species contributes about 13 percent of the seedlings and saplings, has about equal density in pole-sized trees to *Tsuga heterophylla* and *Abies amabilis*, and is second to *Tsuga heterophylla* in large-sized trees of the overstory canopy (all these statistics being averages). *Abies amabilis* dominates tree reproduction with 77 percent of seedling density, whereas *Tsuga heterophylla* is third (after *Chamaecyparis*) with 9 percent.

The shrub layer is similar to that of the *Vaccinium alaskaense* phase, namely dominance by *Vaccinium alaskaense* (33 percent cover) and presence of *V. ovalifolium* (averaging 9 percent cover), *V. membranaceum* (6 percent cover), and some minor shrubs (Table 6). The herbaceous layer, however, is usually quite sparse (averaging only about 8 percent cover). The only herbs which exceed 1 to 2 percent cover when present in a stand are *Linnaea borealis*, *Rubus pedatus*, and (in one plot) *Cornus canadensis*.

With so few plots, we were unable to distinguish environments that consistently differ from those of the *Vaccinium alaskaense* phase. Possibly a greater tendency of fog condensation or other unmeasured en-

vironmental feature contributes to the increased importance of *Chamaecyparis nootkatensis*. Increased snowpack can be speculated as one cause for the general reduction in herb cover.

General Relationships of Type—Forests comparable to the ABAM/VAAL Association have been described from many locales in the Cascade Range. Franklin (1966) described an *Abies amabilis/Vaccinium alaskaense* association as the climatic climax for the *Abies amabilis* Zone in southern Washington. He also recognized four phases: typical, *Berberis nervosa*, *Berberis nervosa-Xerophyllum tenax*, and *Xerophyllum tenax*. Brockway et al. (1983) describe this association as being, ". . . Widespread on environmentally moderate sites" in the Gifford Pinchot National Forest. The type apparently occurs as far south as the central Oregon Cascade Range, where a similar *Abies amabilis/Vaccinium alaskaense/Cornus canadensis* association has been widely recognized (Dyrness et al. 1974, Hemstrom et al. 1982). The *Tsuga heterophylla/Vaccinium alaskaense* community type of del Moral and Long (1977) appears much broader than our ABAM/VAAL Association, based upon the average coverage of wet-site species (such as *Oplopanax horridum*) and dry-site species (such as *Gaultheria shallon* and *Berberis nervosa*) in their stands.

The ABAM/VAAL Association appears to be also common in the Cascade Range north of Mount Rainier to at least the Mount Baker area (Henderson and Peter 1981, 1985). It appears that there may be a shift toward the *Rubus pedatus* phase in the northern Washington area, however, and it is possible that our phase is actually the southern representation of the major modal type in the North Cascades. Henderson and Peter (1985) recognized an *Abies amabilis/Rubus pedatus* Association as distinct from a *Rubus pedatus*-rich ABAM/VAAL type in the Mount Baker area. The extensive occurrence of a similar type in the Olympic Mountains (*Abies amabilis-Tsuga heterophylla* of Fonda and Bliss (1969)) also suggests that the *Rubus pedatus* phase of the ABAM/VAAL Association may predominate at wetter mountain elevations to the north and west of Mount Rainier.

All phases considered together, the ABAM/VAAL Association is related to and forms ecotones with a wide variety of other habitat types. On adjacent warmer and drier slopes, the *Abies amabilis/Berberis nervosa* or *Abies amabilis/Gaultheria shallon* Associations may be encountered. At higher elevations, transitions to *Abies amabilis/Xerophyllum tenax* on upper slopes and ridgetops are found. ABAM/OPHO often forms sharp ecotones with ABAM/OPHO such as in the Ohanapecosh River Valley (East Side trail between Grove of the Patriarchs and Chinook Creek). On slopes, ABAM/VAAL can interface or form mosaics with ABAM/TIUN; the abundance of mesic herbs such as *Tiarella*

unifoliata, *Achlys triphylla*, and *Streptopus roseus* and the sparsity of ericaceous shrubs on ABAM/TIUN distinguish it from ABAM/VAAL. Finally, ABAM/VAAL can intergrade to the *Abies amabilis*/*Menziesia ferruginea* Association in progressing to cooler environments with increased elevation or northerly exposures.

Abies amabilis/*Vaccinium alaskaense* is the most extensive association throughout Mount Rainier National Park. Forests may appear somewhat bland and repetitive compared with the lush herbaceous types of wetter environments. They are quite resilient under use, however, and well suited to developments such as campgrounds and trails. A part of the Cougar Rock campground is on the *Vaccinium alaskaense* phase of the habitat type. In general, the *Abies amabilis*/*Vaccinium alaskaense* habitats have few unique attributes (other than commonness) or, fortunately, problems regarding wildlife, visitors, fire, or other phenomena.

Dry Forest Ecosystems

The group of dry forest ecosystems includes four associations and three community types; the *Abies amabilis*/*Xerophyllum tenax* could also be considered with the cold group. All three *Pseudotsuga menziesii* community types are included here for convenience, although one (*Pseudotsuga menziesii*/*Viola sempervirens*) is more modal or moist than dry in its characteristics. With that exception, all of the types can be considered to be relatively dry with trees typically suffering at least minor moisture deficiencies every year. The *Tsuga heterophylla*/*Gaultheria shallon* and *Abies amabilis*/*Gaultheria shallon* probably also suffer from nitrogen deficiencies.

Tree data for the dry group of forest communities are presented in Table 7. Herb and shrub presence and cover are presented in Table 8.

***Tsuga heterophylla*/*Gaultheria shallon* Association**

The *Tsuga heterophylla*/*Gaultheria shallon* Association (TSHE/GASH) characterizes hot, dry slopes and ridges at low elevations. It is most common in the Ohanapecosh and Nisqually River drainages. It is mostly a forest of mountain sideslopes with south to west exposures. Our plots ranged between 550 and 1190 m (1,815 and 3,330 ft) in elevation. Soils are commonly colluvial or well-drained tephras with only weakly developed spodic horizons.

Mature forests are dominated by *Pseudotsuga menziesii* and *Tsuga heterophylla*, the former usually more abundant (Table 7). *Thuja plicata* and occasional specimens of *Pinus monticola* are less common components of the overstory. The most important reproductive tree is *Tsuga heterophylla*, but regeneration densities may be very low; stocking of

Table 7. Average tree density (stems per hectare) for the dry forest types by species and stem-diameter class, Mount Rainier National Park.

			Stem-diameter class[4]													
		Basal	≤1[5]													
Type and species[1]	Con[2]	area[3]	≤1.4 m	>1.4 m	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	>12
Tsuga heterophylla/Gaultheria shallon Association																
Tsuga heterophylla	94	16.9	1,094	135	81	30	22	7	14	7	3	4		1		
Pseudotsuga menziesii	88	33.5	35	44	25	28	31	21	19	21	13	8	1	1	1	
Abies amabilis	47	0.5	141	9	5	5	1									
Thuja plicata	41	3.5	12	53	10	10	9	5	3	1						
Pinus monticola	12	0.0	35													
Abies grandis	6	0.0	12	7												
Chamaecyparis nootkatensis	6	0.0		2												
All species[6]		54.4	1,329	250	122	74	63	34	36	29	16	12	1	3	1	
Pseudotsuga menziesii/Ceanothus velutinus Community Type																
Pseudotsuga menziesii	100	5.5	1,700	246	63	35	23									
Abies procera	83	2.3	500	19	7	15		4	4							
Pinus monticola	67	0.7	300	94	28											
Tsuga heterophylla	50	0.1		40												
Abies amabilis	17	0.5		4	7	7										
Chamaecyparis nootkatensis	17	0.3		24	16											
Tsuga mertensiana	17	0.0		8												
All species[6]		9.4	2,500	435	121	57	23	4	4							
Pseudotsuga menziesii/Xerophyllum tenax Community Type																
Pseudotsuga menziesii	94	17.6	259	233	109	63	28	26	5	6	4	1				
Abies amabilis	65	0.9	59	15	9	5	2	1								
Tsuga heterophylla	53	2.9	118	62	24	17	7	5								
Abies procera	47	1.5	94	25	7	6	1	1	3							
Pinus monticola	47	0.5	141	52	9	1		1								
Abies lasiocarpa	35	0.2	106	29	2	1										
Tsuga mertensiana	24	1.3	141	15	20	6	4		1							
Chamaecyparis nootkatensis	18	0.1	129	20	4											
Pinus contorta	6	0.1			4											
Picea engelmannii	6	0.0	12													
Thuja plicata	6	0.0		3												
All species[6]		25.0	1,059	454	186	100	42	35	9	6	4	1				
Pseudotsuga menziesii/Viola sempervirens Community Type																
Pseudotsuga menziesii	100	41.2	111	126	67	111	118	71	19	15	2	1	1			
Tsuga heterophylla	94	2.2	744	124	22	12	7	2								
Abies amabilis	83	0.4	156	21	15	2										
Abies procera	44	0.4	33	9	4	1	2									
Pinus monticola	39	0.0	256	13	1											
Thuja plicata	22	2.1	178	127	15	1	1	1		2	1					
Abies grandis	11	0.1	200	5		2										
Populus trichocarpa	6	0.1					1									
Picea engelmannii	6	0.1				1										
Chamaecyparis nootkatensis	6	0.0		6												
Alnus rubra	6	0.0		3												
Abies lasiocarpa	6	0.0		1												
Tsuga mertensiana	6	0.0		1												
All species[6]		46.7	1,678	436	124	130	129	74	19	17	3	1	1			
Abies amabilis/Gaultheria shallon Association																
Tsuga heterophylla	100	42.6	2,400	220	60	64	58	34	33	29	16	2		1		
Abies amabilis	93	3.0	3,267	176	27	30	7									
Thuja plicata	87	7.3	413	91	20	14	23	17	5							
Pseudotsuga menziesii	80	17.8	53	1		3	16	9	16	6	5	5	5			

Table 7. Continued

Type and species[1]	Con[2]	Basal area[3]	Stem-diameter class[4] ≤1[5] ≤1.4 m	Stem-diameter class[4] ≤1[5] >1.4 m	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	>12
Abies procera	27	0.6	80	1	1		1		2							
Chamaecyparis nootkatensis	20	0.9	107	13	5	3	2	3								
Pinus monticola	13	0.0	67													
All species[6]		72.2	6,387	502	113	114	107	64	56	35	21	6	5	1		
Abies amabilis/Berberis nervosa Association																
Tsuga heterophylla	95	34.2	1,142	140	50	34	29	15	18	14	9	9	5	2	1	2
Pseudotsuga menziesii	89	47.5	26	11	21	30	33	24	17	9	15	10	8	2	3	5
Abies amabilis	84	4.2	1,537	256	56	7	9	2	1	1	2					
Abies procera	42	6.3	47	5	2	2	5	2	2	2	1	1	1		1	1
Thuja plicata	39	4.2	189	28	10	12	5	3	1	1	1	1		1		
Pinus monticola	16	1.0	5		1		1		1							1
Chamaecyparis nootkatensis	11	0.8	26	4	1					1					1	
Abies lasiocarpa	5	0.1	16	2	1	1										
Picea engelmannii	3	0.0	5													
All species[6]		98.3	2,995	446	142	86	82	46	40	27	27	21	14	5	6	8
Abies amabilis/Xerophyllum tenax Association, *Tsuga heterophylla* Phase																
Tsuga heterophylla	100	47.4	329	43	33	25	23	36	44	34	8	11	4	3		
Abies amabilis	100	6.7	4,786	307	59	30	15	6	3	1						
Pseudotsuga menziesii	64	18.3					5	2	3	12	6	5	5	3	2	
Chamaecyparis nootkatensis	57	3.6	100	32	16	17	9	10								
Abies procera	43	19.9	86	9	2	2	7		1	10	3	7	7	2	1	2
Tsuga mertensiana	29	4.2				1	3	4	4	5	1					
Thuja plicata	21	0.4	14			1			1							
Pinus monticola	14	1.2	14					1		3						
Abies lasiocarpa	7	0.0		2												
All species[6]		101.7	5,329	392	109	76	62	59	57	64	19	23	16	8	3	2
Abies amabilis/Xerophyllum tenax Association, *Tsuga mertensiana* Phase																
Abies amabilis	100	49.1	8,618	452	45	32	58	72	61	29	8	2				
Tsuga mertensiana	82	4.5	127	23	10		4	12		6						
Chamaecyparis nootkatensis	82	2.6	345	106	19	12	2	8								
Tsuga heterophylla	55	3.3	36		2			4		2	2	2				
Abies procera	45	10.6		2				6	8	4	10				2	
Abies lasiocarpa	45	1.9	73	8	9	6	4	4	2							
Pseudotsuga menziesii	9	0.1				2										
Pinus monticola	9	0.0	36	2												
All species[6]		72.2	9,236	592	84	51	69	107	71	41	20	4			2	
Abies amabilis/Xerophyllum tenax Association, Seral Phase																
Abies amabilis	100	11.8	3,743	106	43	39	22	14	10	7						
Abies lasiocarpa	71	16.8	371	173	91	90	61	15	4	4						
Pseudotsuga menziesii	71	11.3		101	48	22	32	19	13							
Tsuga heterophylla	71	6.0	2,343	93	44	31	15		9							
Tsuga mertensiana	71	1.0	86	9	3	7		4								
Chamaecyparis nootkatensis	71	0.4	86	54	6	3										
Pinus monticola	57	0.9	657	76		3	6									
Abies procera	29	0.1		15	3											
Thuja plicata	29	0.1		13	3											
All species[6]		48.5	7,286	641	241	196	136	52	36	11						

[1]Species are ordered within type by constancy.
[2]Constancy, expressed as percent of sample containing the species.
[3]Expressed as meters squared per hectare.
[4]Decimeters (dm) in diameter at breast height (1.4 m above the ground).
[5]The ≤1 dm diameter class is subdivided into two classes based on height.
[6]Column sums may not be exact due to rounding error.

Table 8. Constancy and characteristic cover of all shrub and herb taxa for the dry forest community types of Mount Rainier National Park.

	Community type[1]																			
	8. TSHE/ GASH		9. PSME/ CEVE		10. PSME/ XETE		11. PSME/ VISE		12. ABAM/ GASH		13. ABAM/ BENE		14a. ABAM/XETE TSHE phase		14b. ABAM/XETE TSME phase		14c. ABAM/XETE Seral phase	
Number of plots per type:	17		6		17		18		15		38		14		11		7	
Taxa	Con	Cov[2]	Con	Cov	Con	Cov	Con	Cov	Con	Cov	Con	Cov	Con	Cov	Con	Cov	Con	Cov	Con	Cov
SHRUBS																				
Cornus nuttallii	18	T																		
Prunus emarginata			17	1																
Sambucus spp.	6	1			12	3														
Ceanothus velutinus			83	7							3	1								
Lonicera ciliosa	29	T					6	1			8	T								
Salix scouleriana			50	1	6	1					5	T								
Symphoricarpos mollis	47	1	33	T	6	T	28	1			26	1								
Holodiscus discolor	6	T	17	T	6	T	6	T			5	1								
Corylus cornuta	6	T	17	5	6	T	6	T			5	1								
Arctostaphylos uva-ursi			100	5	29	12	22	T			5	1	7	1			14	10		
Gaultheria shallon	100	49			35	10	33	1	100	22	26	2	14	2			14	3		
Amelanchier alnifolia	47	1	67	3	24	1	56	1			29	T					29	1		
Acer circinatum	65	17	67	10	47	8	89	14			47	12	7	T			29	1		
Acer glabrum	6	5			6	3	6	T			5	3								
Rubus parviflorus			67	1	18	2	28	4			16	T								
Rosa gymnocarpa	53	2	67	1	35	T	61	1	7	T	58	1			9	T				
Rubus spectabilis					12	T	11	8	7	T	3	T								
Rubus ursinus	53	T	83	3	47	2	89	1	20	T	61	1	7	T			14	T		
Phyllodoce empetriformis					18	1									9	T				
Taxus brevifolia	65	7					11	1	60	12	42	1	7	1						
Alnus sinuata					18	4	17	5									14	4		
Vaccinium parvifolium	88	5	33	2	53	6	67	5	100	5	66	2	36	3	9	T	14	T		
Pachistima myrsinites	65	T	100	1	76	1	61	T	47	T	63	1	29	T	9	T	57	1		
Berberis nervosa	100	8	83	1	53	5	72	8	93	7	100	9	50	4			29	4		
Ribes howellii					6	1					3	T								
Sorbus sitchensis	12	T	33	T	18	1	39	T			13	1	14	T	9	T	14	3		
Ribes bracteosum					6	2	17	T							9	T				
Chimaphila umbellata	88	2	50	T	53	1	83	2	100	2	92	3	50	3			57	1		
Gaultheria ovatifolia	47	1	50	T	71	7	78	2	67	2	39	1	43	2	18	2	71	3		
Chimaphila menziesii	47	T	17	T	6	T	28	T	73	T	55	T	29	T			14	T		
Cornus canadensis	29	T	17	1	29	4	72	5	60	1	58	2	29	2	9	1	14	T		
Vaccinium alaskaense	35	3	17	T	24	T	39	1	80	10	32	1	50	2	9	5	29	13		
Vaccinium deliciosum					12	3					3	T			9	1				
Vaccinium ovalifolium	35	T	17	T	24	1	28	6	53	2	16	T	36	1	36	2	43	7		
Menziesia ferruginea	29	T	17	T	41	2	33	1	47	1	11	T	57	T	45	1	71	8		
Vaccinium membranaceum	53	1	83	7	71	20	61	2	80	6	76	1	100	4	100	18	100	21		
Rubus lasiococcus	18	T	83	2	65	4	78	4	20	T	71	1	57	1	91	3	86	5		
Juniperus communis					12	1	6	T							9	T	14	T		
Ribes lacustre					6	T	11	1			26	T								
Oplopanax horridum							17	2			5	T					14	T		
Rubus pedatus	12	T			6	3	11	T	40	T	18	1	21	1	45	2				
Viburnum edule											3	T								
Rubus nivalis											5	T								
Vaccinium scoparium					29	11			13	1	5	1	21	2	18	5	57	1		
Rhododendron albiflorum			17	T			11	1	7	T	3	T	14	1	64	9	14	4		
HERBS																				
Collomia heterophylla	6	T																		
Penstemon menziesii	6	T																		
Apocynum androsaemifolium	18	T																		
Antennaria spp.			17	T																
Collomia spp.			17	T																

Table 8. Continued

Taxa	8. TSHE/ GASH (17)		9. PSME/ CEVE (6)		10. PSME/ XETE (17)		11. PSME/ VISE (18)		12. ABAM/ GASH (15)		13. ABAM/ BENE (38)		14a. ABAM/XETE TSHE phase (14)		14b. ABAM/XETE TSME phase (11)		14c. ABAM/XETE Seral phase (7)	
Community type[1] — Number of plots per type in parentheses	Con	Cov[2]	Con	Cov	Con	Cov	Con	Cov	Con	Cov	Con	Cov	Con	Cov	Con	Cov	Con	Cov
Cinna latifolia			17	T														
Polygonum minimum			17	T														
Agoseris aurantiaca			17	T														
Gayophytum diffusum			17	T														
Agrostis spp.			17	T														
Heuchera spp.	12	2									3	T						
Festuca occidentalis	29	T	17	T	12	T	6	T			8	T						
Polygonum bistortoides					6	T												
Polemonium spp.					6	T												
Galium oreganum			33	1	6	T	11	T										
Viola spp.					6	T												
Trisetum spicatum					6	T												
Calamagrostis spp.					6	1												
Anaphalis margaritacea			100	1	35	T	17	T			5	T						
Pteridium aquilinum	71	1	100	39	53	18	94	13	7	T	16	11	7	T			43	1
Fragaria vesca	24	T	83	4	41	T	83	1			11	T					14	1
Lithospermum californicum	41	T	17	T			28	T			16	T	7	T				
Saxifraga spp.	6	T					6	T			3	4						
Hemitomes congestum	6	T							13	T								
Listera cordata	65	T			29	T	39	T	13	T	16	T	7	T			43	T
Festuca subulata							6	T										
Circaea alpina	6	T			6	T					5	3						
Petasites frigida							6	T										
Corallorhiza mertensiana	6	T											7	T				
Veronica spp.							6	T										
Arenaria macrophylla	6	1	33	1	6	T	11	1			11	T						
Adiantum pedatum							6	T										
Trifolium latifolium	47	2	33	3	18	1	61	1			45	1						
Epilobium angustifolium			100	T	59	T	39	T	13	T	5	T			9	T	43	T
Campanula scouleri	6	2			12	T	22	T			8	T						
Hieracium albiflorum	47	1	100	1	71	T	78	1	13	1	32	T					86	T
Gilia sp.	6	T					17	T			5	T						
Bromus suksdorfii	6	T					17	T			5	T						
Smilacina stellata	35	T	33	1	24	1	94	2			50	1						
Blechnum spicant	12	T					17	T	20	T	8	2						
Carex spp.			17	5	12	T					8	T						
Mitella spp.					6	1	6	T			3	T						
Adenocaulon bicolor	12	T					28	T			16	T						
Achlys triphylla	65	5	83	2	47	2	94	8			84	4	14	T	9	T	43	1
Streptopus amplexifolius					6	T					3	T						
Pedicularis racemosa	24	T	33	1	24	T	39	1	7	T	5	1	7	T			71	1
Bromus vulgaris	24	1	33	4	18	T	56	T			26	1	14	T			29	T
Anemone deltoidea	12	T					17	T			8	T					14	T
Listera borealis	88	2			53	4	94	12	93	4	76	5	50	2			43	7
Athyrium filix-femina					6	T	11	10			5	T						
Galium triflorum	12	T			6	T	61	T			24	T			9	T		
Polystichum munitum	24	2	17	T	6	T	33	1			39	T			9	T		
Osmorhiza spp.	6	T	17	T	6	T	44	T			11	1	7	T	18	T		
Lilium columbianum	29	T	17	T	6	T	33	T	40	T	8	T	7	T	9	T	57	T
Disporum hookeri			17	T			17	T			11	T						
Anemone lyallii							28	T			8	1						
Pyrola asarifolia	35	T			6	T	56	T	40	T	37	1	14	1			29	1
Nothochelone nemorosa	18	1	50	T	29	T	22	T			24	1	14	T	9	T	43	1

Table 8. Continued

	Community type[1]																	
	8. TSHE/ GASH		9. PSME/ CEVE		10. PSME/ XETE		11. PSME/ VISE		12. ABAM/ GASH		13. ABAM/ BENE		14a. ABAM/XETE TSHE phase		14b. ABAM/XETE TSME phase		14c. ABAM/XETE Seral phase	
Number of plots per type:	17		6		17		18		15		38		14		11		7	
Taxa	Con	Cov[2]	Con	Cov	Con	Cov	Con	Cov	Con	Cov	Con	Cov	Con	Cov	Con	Cov	Con	Cov
Lupinus latifolius	6	2	33	1	35	6	28	1	7	5	5	T	7	T	9	1	57	1
Viola sempervirens	53	1	67	T	47	1	100	5	40	1	76	1	50	T	45	T	71	1
Viola glabella	12	T					33	T			13	1	7	1	9	T	14	1
Aster canescens							22	T			11	T						
Smilacina racemosa							17	T			8	T						
Gymnocarpium dryopteris							11	3			5	18						
Montia spp.							6	T			3	T						
Agropyron spp.			17	T			6	1									14	T
Goodyera oblongifolia	76	T			12	T	50	T	53	T	79	T	43	1	36	T	43	T
Trillium ovatum	24	T			6	T	61	T	7	T	53	T			9	T	29	T
Pyrola picta	12	T					6	T			26	T						
Tiarella unifoliata	18	T					56	4			50	1	14	1	9	T		
Xerophyllum tenax	53	16	67	2	82	35	44	4	93	14	29	2	100	26	100	33	100	49
Carex rossii			33	6			6	T									29	T
Allotropa virgata									33	T	5	T						
Tiarella trifoliata	6	T					6	T			16	1	7	T				
Polystichum lonchitis							6	T			5	2						
Lycopodium clavatum									13	T	3	T						
Actaea rubra							6	T			8	T						
Clintonia uniflora	12	T	33	T	24	T	50	1	13	T	76	1	21	1	55	2	29	1
Arnica latifolia					6	T	28	1			5	1	7	2	18	3	14	6
Corallorhiza maculata							11	T			3	T	14	T				
Pyrola virens							6	T			11	T						
Corallorhiza spp.	12	T					6	T	67	T	47	T	50	T	27	T		
Pyrola secunda			33	T	29	T	67	T	27	1	71	1	64	2	73	1	71	1
Trautvetteria grandis							6	T							9	T		
Pyrola uniflora											5	1						
Ligusticum grayi					6	T							7	T	9	T		
Polemonium pulcherrimum											5	T						
Dryopteris austriaca											3	T						
Calypso bulbosa											5	T						
Madia dissitiflora											8	T						
Streptopus roseus					6	T	11	T			21	T	7	4	27	2	14	T
Luzula parviflora			17	T							5	T	14	T	18	T		
Valeriana sitchensis					6	T	6	T			8	T	7	T	36	2	14	T
Streptopus streptopoides													14	T				
Veratrum viride							6	T							27	T		
Hydrophyllum spp.													14	T				
Erythronium montanum					6	1							14	T	45	8		
Hypopitys monotropa															45	1	57	T
Average total shrub cover[3]	82		33		44		34		57		20		10		26		42	
Average total herb cover[4]	20		56		50		56		21		22		32		44		65	

[1]Community type names and numbers correspond with those in Table 1.
[2]Constancy (Con) is the percent occurrence of a species in the plots assigned to each forest type. Characteristic cover (Cov) is the average cover of a species computed by averaging over only those plots where it occurs. Values are rounded to nearest percent. Values less than 0.5% are denoted by 'T'.
[3]Average total shrub cover is computed by summing the shrub cover on each plot then averaging those totals over all plots in a type.
[4]Average total herb cover is computed by summing the herb cover on each plot then averaging those totals over all plots in a type.

saplings and poles in our plots ranged from 0 to about 220 stems/ha (88/acre). In some stands there were minor amounts of sapling *Abies amabilis* or *Thuja plicata*; these were always far less abundant than *Tsuga heterophylla*.

Acer circinatum may form a conspicuous tall shrub layer (up to 60 percent cover) (Fig. 20), but it can also be minor or absent (Table 8). Other species of this stratum are *Taxus brevifolia* (1 to 5 percent cover, although one exceptional plot had 60-percent cover) and occasional *Amelanchier alnifolia*. The lower shrub layer dominated by *Gaultheria shallon* is a diagnostic feature of this association. *Gaultheria shallon* cover averages 47 percent (range from 2 to 85 percent). Other rather common shrubs are *Berberis nervosa* (up to 40-percent cover), *Vaccinium parvifolium* (1 to 12 percent cover), *Vaccinium membranaceum, Rosa gymnocarpa*, and *Symphoricarpos mollis*. Important evergreen herbs of this habitat are *Chimaphila umbellata* and *Linnaea borealis*, whereas *Xerophyllum tenax* occurs in about half of the sample plots. Crown perennials are relatively inconspicuous in the herbaceous stratum, but *Achlys triphylla, Festuca occidentalis, Hieracium albiflorum, Listera cordata, Trientalis latifolia*, and *Pteridium aquilinum* are occasional, moderately constant species (appearing in 30 percent or more of the plots).

Pseudotsuga menziesii is a principal seedling or sapling in young stands, but *Thuja plicata, Tsuga heterophylla*, and *Pinus monticola* also have moderate to heavy densities. *Gaultheria shallon* and *Pteridium aquilinum* averaged 60 and 5 percent cover, respectively, in three stands less than 100 years old.

This association of hot, dry slopes has poor growth rates of tree diameter and height. Many stands, especially in the Ohanapecosh drainage, are even-aged—about 250 years old. Some of these appear relatively stagnant, for succession to the *Tsuga heterophylla*-dominated climax appears very slow. The TSHE/GASH forests show rather heavy wildlife usage, particularly by browsing deer and elk. Active game trails are conspicuous. Important browse species include *Acer circinatum, Vaccinium parvifolium, Amelanchier alnifolia*, and saplings of *Thuja plicata*. Dwarf mistletoe (*Arceuthobrium campylopodum*) is a major pathogen on *Tsuga heterophylla* in this and the *Abies amabilis/Gaultheria shallon* Association.

Mosaics of TSHE/GASH with other forest types are particularly evident near the Ohanapecosh campground and along the Silver Falls trail. Juxtapositions of TSHE/GASH, TSHE/OPHO, TSHE/ACTR, and the *Berberis nervosa* phase of ABAM/VAAL Associations can all be found. The TSHE/GASH type occurs on the driest microsites. At higher elevations, TSHE/GASH intergrades to the *Abies amabilis/Gaultheria shallon* Association. Relatively dry midslope environments may have mosa-

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Figure 20. *Acer circinatum* may form a significant tall shrub layer over the uniformly present *Gaultheria shallon* in the *Tsuga heterophylla/Gaultheria shallon* habitat type. Near the Ohanapecosh entrance.

ics of TSHE/GASH and *Abies amabilis/Berberis nervosa* types, the former on slightly hotter or drier microsites.

Comparable ecosystems are widespread in western Washington and Oregon, our type evidently representing an upper-elevational variant. Henderson and Peter (1981) describe TSHE/GASH as the most common association on the White River District of the Snoqualmie National Forest. It has also been identified on the Gifford Pinchot National Forest (Topik et al. 1985), especially "in minor rainshadow areas." In the Cedar River drainage, the *Pseudotsuga menziesii/Gaultheria shallon* community type of del Moral and Long (1977) apparently occurs on this habitat type. In the Oregon Cascade Range, habitats characterized by *Gaultheria shallon* typically include *Rhododendron macrophyllum* as a tall shrub dominant (Dyrness et al. 1974). In the Olympic Mountains, both the *Pseudotsuga menziesii-Tsuga heterophylla* and *Pseudotsuga menziesii* types (Fonda and Bliss 1969) appear environmentally and floristically related to our TSHE/GASH Association.

Pseudotsuga menziesii/Ceanothus velutinus Community Type

Extensive areas of young *Pseudotsuga menziesii* stands 50 to 100 years old occur in the Cowlitz and Ohanapecosh River drainages. Similar stands also occur in other locations in the Park, such as on Crystal Mountain in the White River drainage. It is very difficult to successionally relate many of these youthful communities to the mature associations. These stands have, therefore, been grouped into three *Pseudotsuga menziesii* types.

The *Pseudotsuga menziesii/Ceanothus velutinus* (PSME/CEVE) community samples are from two recently burned sites in the Ohanapecosh drainage—the Shriner Burn (last burned in 1934) and an unnamed burn on the north side of Deer Creek. This community occupies moderate to steep, southerly exposed slopes at low to middle elevations. Soils are colluvial and often shallow and stony. The PSME/CEVE type is obviously characteristic of severe (hot and droughty) habitats that have been recently (within the last 100 years) and probably repeatedly burned (Fig. 21).

Figure 21. The *Pseudotsuga menziesii/Ceanothus velutinus* community type is found on exposed southerly sites that have reburned several times during recent centuries. A typical area of this community is apparent here in the Shriner Peak burn which last burned in 1934.

Pseudotsuga menziesii is the most important tree species (Table 7). *Abies procera* is important on one plot but is not characteristic. Other tree species include *Pinus monticola*, *Abies amabilis*, and *Tsuga heterophylla*. Basal areas are low in these stands, which are still in a regenerating phase (see Fig. 21).

Understories have moderate densities on the average, although individual sites may be very brushy (Table 8). *Acer circinatum*, *Ceanothus velutinus*, and *Vaccinium membranaceum* provide most of the 33 percent shrub cover. Shrubs occurring in most plots (80 percent presence or more) are *Berberis nervosa*, *Arctostaphylos uva-ursi*, *Pachystima myrsinites*, *Rubus ursinus*, and *Vaccinium membranaceum*. The herb layer is poorly developed but includes many early successional species; *Pteridium aquilinum*, *Epilobium angustifolium*, *Hieracium albiflorum*, and *Anaphilis margaritacea* all have 100 percent presence.

As mentioned, this community appears to represent early forest development on intensely burned, warm, droughty sites. These sites may represent xeric phases of the *Abies amabilis/Berberis nervosa* habitat type.

***Pseudotsuga menziesii/Xerophyllum tenax* Community Type**

The *Pseudotsuga menziesii/Xerophyllum tenax* (PSME/XETE) community occurs throughout the Park. Stands range from 48 to 142 years old. The habitat is found on gentle to moderate, southerly exposed slopes and appears to occupy somewhat less stressful environments than does the PSME/CEVE type. Our plots range widely in elevation, from 800 to 1580 m (2,640 to 5,210 ft). Soils are colluvial, often including substantial tephra.

Pseudotsuga menziesii strongly dominates this community, especially in pole sizes (Table 7). *Tsuga heterophylla*, *Abies amabilis*, *Pinus monticola*, and *Abies procera* are regular minor associates.

The PSME/XETE community has a substantial understory of both shrubs and herbs (Fig. 22 and Table 8). Important shrubs include *Gaultheria ovatifolia*, *Pachystima myrsinites*, *Acer circinatum*, *Vaccinium membranaceum*, and *Vaccinium parvifolium*. *Gaultheria shallon* and *Berberis nervosa* have substantial coverage when present. *Xerophyllum tenax*, which averages 28 percent cover, comprises about half of the herb cover. Other important herbs are *Pteridium aquilinum*, *Linnaea borealis*, and *Rubus lasiococcus*.

The PSME/XETE type is believed to occur mainly on sites assignable to the *Abies amabilis/Gaultheria shallon* Habitat Type. This is based upon the combination of *Gaultheria* spp., *Xerophyllum tenax*, and *Acer circinatum* as important species. The community may also be successional to the *Abies amabilis/Xerophyllum tenax* Association—especially those stands at higher elevations. The *Gaultheria* spp. suggest

Figure 22. *Pteridium aquilinum* dominates the understory of this 91-year-old *Pseudotsuga menziesii/Xerophyllum tenax* community on Backbone Ridge. The meter stick is near a charred snag.

that the *Abies amabilis/Berberis nervosa* association is an unlikely climax to the sere. Nevertheless, the wide elevational span of forests classified in this community type and the different sectors of the Park where it is found lead us to suspect that at least several habitat types may have PSME/XETE communities as seral forests.

Pseudotsuga menziesii/Viola sempervirens Community Type

The *Pseudotsuga menziesii/Viola sempervirens* Community Type (PSME/VISE) occurs mainly in the Cowlitz, Ohanapecosh, and White River drainages at elevations between 720 and 1280 m (2,380 and 4,220 ft). The ages of trees in our plots ranged from 72 to 153 years. Most stands were on gentle to moderate slopes, on all aspects, and had colluvial and tephra soils (Hobson 1976).

The community type is strongly dominated by pole- and standard-sized *Pseudotsuga menziesii* (Table 7). This is the most productive of the *Pseudotsuga menziesii* communities as reflected in basal areas. Associated overstory trees include *Abies amabilis, A. procera, Tsuga het-*

erophylla, and *Thuja plicata*. On the average, the most important seedlings are *Tsuga heterophylla* and the most important saplings are *Abies amabilis*. *Pseudotsuga menziesii* can also be well represented by saplings.

The PSME/VISE type has a dense herbaceous layer (Fig. 23) and highly variable shrub layer (Table 8). Dominant herbs include the pioneer fern, *Pteridium aquilinum*, found in 90 percent of our plots, and mesic species such as *Viola sempervirens*, *Achlys triphylla*, *Linnaea borealis*, *Rubus lasiococcus*, and *Cornus canadensis*. Collectively these herbs contribute about three-fourths of the average herb cover of 54 percent over the 18 sample plots. No shrub species was present in all plots, but the most important shrubs of this community type are *Acer circinatum*, *Berberis nervosa*, *Vaccinium parvifolium*, *V. membranaceum*, and *Gaultheria ovatifolia*.

We are uncertain about the successional status of this community type. Stands of the PSME/VISE type are often found adjacent to stands of the ABAM/VAAL Association, occupying the same landform and

Figure 23. Representative stand of the *Pseudotsuga menziesii/Viola sempervirens* community type; note the rich herbaceous understory, nearly pure *Pseudotsuga menziesii* stand, and snag of *Thuja plicata* still persisting 75 years after the last wildfire.

slope positions. If these forests are successionally related, then *Vaccinium alaskaense* and its ericaceous shrub associates obviously develop in midsere. On the other hand, the rich herb complement and slope and landform positions of still other stands classified as the PSME/VISE type are also suggestive of the TSHE/ACTR Association.

***Abies amabilis/Gaultheria shallon* Association**

The *Abies amabilis/Gaultheria shallon* Association (ABAM/GASH) occurs mostly in the wesern half of the Park, in the Nisqually, Puyallup, and Mowich River drainages. It is typically encountered on moderate to steep, southerly exposed, middle and upper slopes; the mean slope and aspect (51 percent and 194°) of our plots are indicative of a relatively warm, dry environment. Elevational range is from 900 to 1300 m (2,970 to 4,290 ft). Tephra and alluvium are about equally important as soil parent materials.

Tsuga heterophylla and *Pseudotsuga menziesii* dominate mature stands (Table 7). *Thuja plicata* and *Abies amabilis* can be important associates in smaller size classes. *Tsuga heterophylla* and *Abies amabilis* are, on the average, of equal importance in reproductive size classes; typically, reproduction of *Thuja plicata* is also present in small quantities.

Understories of the ABAM/GASH type are strongly dominated by evergreens in the shrub layer and *Gaultheria shallon* and *Xerophyllum tenax* in the herb layer (Fig. 24 and Table 8). Other shrubs include evergreen species such as *Berberis nervosa* and *Gaultheria ovatifolia* and deciduous *Vaccinium parvifolium* and *Vaccinium alaskaense*. Common evergreen herbs, but with minor coverage, are *Chimaphila umbellata* and *Linnaea borealis*.

Understory coverage in young communities varies widely from rank to nearly absent, depending upon stand density. *Pseudotsuga menziesii* is the major seral species, but *Tsuga heterophylla* can also dominate young stands, especially at higher elevations. Some of the stands included in the PSME/XETE Community Type are probably representative of seral stages on ABAM/GASH habitat type.

Because of low productivity, stands belonging to this association are typically unimpressive. The *Tsuga heterophylla* are often heavily infected by dwarf mistletoe and the *Gaultheria* spp.-dominated understory is monotonous. On the other hand, the plant cover is resilient and will stand up under heavy use; with the prevalence of tree diseases on this habitat, hazardous trees require special attention.

The ABAM/GASH Association is most clearly related to the TSHE/GASH type, into which it grades at its lower elevational limit, and the *Tsuga heterophylla* phase of the *Abies amabilis/Xerophyllum tenax* Association at its upper elevational limits. The abundance of *Abies*

Figure 24. Understory of a stand in the *Abies amabilis/Gaultheria shallon* habitat type.

amabilis and *Xerophyllum tenax* in the ABAM/GASH type differentiates it from TSHE/GASH. The presence of *Gaultheria* and several other warm-site species differentiates ABAM/GASH from *Abies amabilis/Xerophyllum tenax*. A third, closely related, dry, slope association is *Abies amabilis/Berberis nervosa*, although it essentially lacks both *Gaultheria shallon* and *Xerophyllum tenax*.

Comparable associations have been described in the southern Washington Cascade Range (Franklin 1966, Brockway et al. 1983) as well as in areas to the north (Henderson and Peter 1981). We have observed comparable types in regions of southeastern Olympic Mountains, Washington, and Fonda and Bliss' (1969) *Tsuga heterophylla-Pseudotsuga menziesii* type may be related. The *Abies amabilis/Rhododendron macrophyllum-Gaultheria shallon* Association of the northern Oregon Cascade Range has many similarities (Hemstrom et al. 1982).

Abies amabilis/Berberis nervosa Association

The *Abies amabilis/Berberis nervosa* Association (ABAM/BENE) is a relatively depauperate habitat type (Fig. 25) that occupies moderately dry, often steep slopes at middle elevations. This type is found most

frequently on the east side of the Park with 29 of our 38 plots in the White and Ohanapecosh River drainages. Elevational range is 750 to 1420 m (2,470 to 4,690 ft). Nearly all the plots are on mountain slopes (all positions), which typically exceed 45 percent. Exposures are generally, but not exclusively, southerly. Colluvium and tephra deposits are equally common soil parent materials; shallow stony soils are the usual features of the steep slopes.

Mature forests belonging to the ABAM/BENE Associations are dominated by *Pseudotsuga menziesii* and *Tsuga heterophylla*, with *Abies procera, Abies amabilis*, and *Thuja plicata* as common associates (Table 7). Seedlings and sapling densities are mainly of *Abies amabilis* and *Tsuga heterophylla* with an average ratio of about 1.5:1.

Understories are typically sparse in both shrub (average cover 20 percent) and herb (average cover 22 percent) layers (see Fig. 25 and Table 8). When present, *Berberis nervosa* and *Acer circinatum* provide the only substantial shrub cover, although *Vaccinium membranaceum, Vaccinium parvifolium, Pachystima myrsinites*, and *Rosa gymnocarpa* are commonly present. *Chimaphila umbellata, Achlys triphylla*, and

Figure 25. Stands in the *Abies amabilis/Berberis nervosa* habitat type often have few plant species and sparse cover in the understory. This stand is near Crystal Creek.

Linnaea borealis are the most important herbs, although others such as *Clintonia uniflora, Viola sempervirens, Pyrola secunda*, and *Rubus lasiococcus* are usually present.

Young stands are often dominated by mixtures of *Tsuga heterophylla, Pseudotsuga menziesii, Abies procera*, and *Pinus monticola*. *Abies amabilis, Thuja plicata*, and even *Abies lasiocarpa* may also be major components of young stands, however. Understories are generally a little richer in young than in old stands.

This habitat type is extensive in the White River drainage. The middle and lower slopes of Shriner Peak and of Sunrise Ridge are largely ABAM/BENE Habitat Type. Much of the habitat type is occupied by stands 50 to 250 years of age, which reflects the greater fire frequency than on ABAM/VAAL habitats (Hemstrom 1982). Young stands are at relatively dynamic stages when extensive mortality can often be expected due to developing competition and subsequent attacks by pathogens. A good example is the extensive destruction of *Pinus monticola* by bark beetles (*Dentroctonus monticolae*) along the Sunrise Ridge road during the 1960's. Such waves or episodes of mortality are a natural pattern.

The ABAM/BENE Association is related to the *Berberis nervosa* phase of ABAM/VAAL and to the ABAM/GASH types. The sparsity of *Vaccinium alaskaense* and other ericaceous shrubs in mature forests and the warmer, steeper slopes distinguish ABAM/BENE from ABAM/VAAL. At lower elevations, some mature forest stands within ABAM/BENE habitat (for example, plots 30, 407, and 426) have little regeneration of *Abies amabilis* compared to *Tsuga heterophylla*. These stands suggest a *Tsuga heterophylla* phase of this type, but our samples were too few to clearly separate such a phase. Nevertheless, we suspect that at the warmer, drier environments within the ABAM/BENE Association there is gradation, especially in tree regeneration characteristics, to a *Tsuga heterophylla/Berberis nervosa* Association, which is more widespread outside the Park boundaries (see Fig. 11).

If the ABAM/BENE is primarily an east-side association, its counterpart on the west side of the Park in comparable environments is the ABAM/GASH type. We considered assigning several plots of the ABAM/BENE Association found in the west half of the Park to the ABAM/GASH Association, but their lack of *Gaultheria shallon* and *Xerophyllum tenax* made them too distinctive. At any rate, we are uncertain just what subtle shifts in environmental features separate these closely related, but geographically variant associations. Perhaps the distinction between these associations disappears to the south of the Park. Franklin's (1966) *Abies amabilis/Berberis nervosa* Association includes substantial amounts of both *Gaultheria shallon* and *Xerophyllum tenax* but is otherwise similar to the *Abies amabilis/Berberis nervosa*

Association at Mount Rainier. The ABAM/BENE Association of Brockway et al. (1983) on the Gifford Pinchot National Forest is quite similar to ours except that it contains a little more *Xerophyllum tenax*. An ABAM/BENE type was the second most common association in the *Abies amabilis* Zone of the White River drainage north of the Park (Henderson and Peter 1981) and extends to the Canadian border (Henderson and Peter 1985). The comparable communities in the Oregon Cascade Range include ABAM/BENE (Hemstrom et al. 1982) and *Tsuga heterophylla-Abies amabilis/Rhododendron macrophyllum/Berberis nervosa* (Dyrness et al. 1974) Associations.

***Abies amabilis/Xerophyllum tenax* Association**

The *Abies amabilis/Xerophyllum tenax* Association (ABAM/XETE) is a rather floristically depauperate type found on steep, dry mountain slopes and ridgetops in the upper *Abies amabilis* and lower *Tsuga mertensiana* Zones. It is perhaps most extensive in the Nisqually River drainage but can be found throughout the Park. The association is most common at midslope and on upper slopes, and on broad or narrow ridgetops. It occupies any aspect, but southerly exposures are most common. Soils are often stony and of colluvial or tephra deposits. Extremely cobbly, skeletal horizons are usually found at depths between 0.5 and 1 m below the soil surface. Plot 100 in this type has a modal colluvial soil as classified by Hobson (1976) and described in the section on soils (Chapter 2). Elevations of the plots range from 960 to 1610 m (3,730 to 5,310 ft). Two elevational phases reflect the major *Tsuga* associate: the *Tsuga heterophylla* phase at lower elevations and *T. mertensiana* phase at higher elevations. The break between phases generally occurs around 1400 to 1500 m (4,600 to 4,950 ft).

Abies amabilis is the most important species in mature forests (Table 7). *Tsuga heterophylla* is the major associate in the *Tsuga heterophylla* phase, but *Pseudotsuga menziesii, Abies procera*, and *Chamaecyparis nootkatensis* may also be conspicuous. *Tsuga mertensiana* and *Chamaecyparis nootkatensis* are the most important associates in the *Tsuga mertensiana* phase. Either one or both *Tsuga* spp. may be important in the transition zone between the two phases (at 1400 to 1500 m or 4,600 to 4,950 ft). About 90 percent of the tree reproduction is *Abies amabilis* in both phases, with *Tsuga heterophylla* (in the *Tsuga heterophylla* phase) and *Chamaecyparis nootkatensis* making minor contributions.

The forest understory of the ABAM/XETE Association is depauperate (Table 8). The shrub and herb layers appear to be composed almost entirely of *Vaccinium membranaceum* and *Xerophyllum tenax*, respectively (Fig. 26). *Pyrola secunda, Rubus lasiococcus*, and *Viola sempervirens* are the only other species occurring in over half the plots; their

cumulative cover averages only 3 percent. The two phases differ in representation by minor understory species. The *Tsuga mertensiana* phase consistently has only the five aforementioned species plus low coverage of *Rhododendron albiflorum* and *Clintonia uniflora*. Stands of the *Tsuga heterophylla* phase, on the other hand, are more likely to include small amounts of *Berberis nervosa, Chimaphila umbellata, Linnaea borealis*, and *Vaccinium alaskaense*, and less likely to include *Rhododendron albiflorum, Clintonia uniflora*, or *Erythronium montanum*.

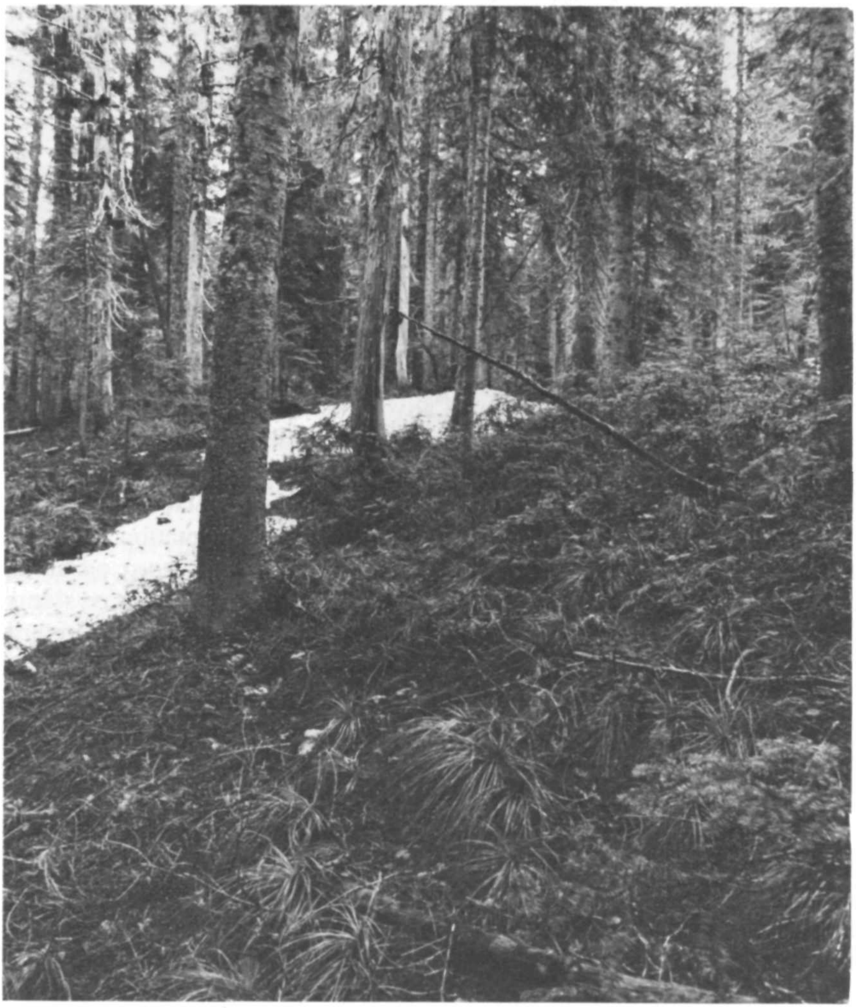

Figure 26. *Xerophyllum tenax* and *Vaccinium membranaceum* dominate the depauperate understories found in *Abies amabilis/Xerophyllum tenax* stands.

Young stands can be dominated by any of several tree species; *Pseudotsuga menziesii*, *Pinus monticola*, *Abies procera*, and *Abies lasiocarpa* are common early successional species. In fact, *Pseudotsuga menziesii*, *Abies procera*, and *Abies lasiocarpa* appear to represent an elevational gradient on slopes from low to high elevations. *Abies amabilis*, *Chamaecyparis nootkatensis*, and *Tsuga* spp. are also important in some young stands. One anomalous young stand containing *Abies lasiocarpa* and *Tsuga mertensiana* in regeneration sizes (as well as *Abies amabilis* and *Tsuga heterophylla*) occurred on a valley mudflow in the Muddy Fork of the Cowlitz River at the 960 m (3,170 ft) elevation. Perhaps cold air drainage is one of the compensatory features of this low elevation stand. The major floristic feature of the young stands is a much greater average cover of *Xerophyllum tenax* (49 percent) and *Vaccinium membranaceum* (21 percent) than that occurring in the mature stands.

This association is frequently encountered by visitors traveling the high forested trails. Its resilient ground vegetation and well-drained soils make it well suited for trails and campsites. *Abies amabilis/Xerophyllum tenax* habitats (like those of the *Abies amabilis/Rubus lasiococcus* type) appear to burn more frequently than most other habitat types because of their position on warmer, drier, upper slopes and ridgetops (Hemstrom 1982). Reforestation may be slow and patchy following fire; extensive historical burns can be seen that are still filling in, such as in the upper Stevens Canyon area.

The abundance of *Xerophyllum tenax* in this association is an important feature. Although most leaves of the plant are consumed in a wildfire, the growing point deep within the clump is protected, and shoot growth resumes almost immediately (Fig. 27). This adaptation to fire is surely responsible for the high coverage of *Xerophyllum tenax* on burns and in immature stands. Rapid regrowth and extensive root systems make it an important protector against soil erosion and helps retard nutrient leaching during the early years after fire. During years of major flowering, *Xerophyllum tenax* is not only esthetically important, but the flowering stalks also provide forage for deer and elk. The plant can also be a curse to the cross-country traveler on steep slopes, especially during wet weather when its leaves offer slippery footholds.

At Mount Rainier, the ABAM/XETE Association is most closely related to the *Abies amabilis/Rubus lasiococcus* and ABAM/GASH types and to the PSME/XETE Community Type. We hypothesize that the *Abies amabilis/Rubus lasiococcus* occupies somewhat moister environments than does the ABAM/XETE Association. The main features distinguishing the *Abies amabilis/Rubus lasiococcus* Association are the low coverage or absence of *Xerophyllum tenax* and an abundance of other herbs. At lower elevations, the *Tsuga heterophylla* phase of the

Figure 27. *Xerophyllum tenax* plants often survive wildfires even though most of the leaves are burned away. Leaves of these plants have resumed growth from surviving meristems buried deep in the clump less than 6 weeks after a wildfire. Headwaters of Deer Creek.

ABAM/XETE Association appears to grade into the ABAM/GASH type to which it is floristically similar. Abundance of *Gaultheria shallon* and *Berberis nervosa* and low coverage of *Vaccinium membranaceum* distinguish ABAM/GASH from ABAM/XETE Associations. The PSME/XETE Community Type is probably a seral stage of the ABAM/GASH Association at lower elevations and possibly of the ABAM/XETE Association at elevations above about 1200 m (3,950 ft). Nevertheless, at these higher elevations, the successional status of the PSME/XETE Community Type remains unclear. Some stands assigned to this type contain *Gaultheria shallon* and *Acer circinatum*, suggesting affinity to the ABAM/GASH Association; whereas other stands lacking substantial coverage of these shrubs appear floristically similar to the ABAM/XETE Association.

Forest communities dominated by *Xerophyllum tenax* and *Vaccinium membranaceum* are apparently widespread. The *Abies amabilis-Tsuga heterophylla/Vaccinium membranaceum* Association of the southern Washington Cascade Range (Franklin 1966) is comparable to the *Tsuga heterophylla* phase. Franklin's (1966) *Abies amabilis-Tsuga mertensiana/Vaccinium membranaceum* Association is comparable to the

Tsuga mertensiana phase of the ABAM/XETE type. Franklin (1966) used *Vaccinium membranaceum* to name his types because *Xerophyllum tenax* is absent from areas of deep, coarse-textured pumice found north and east of Mount St. Helens. The *Abies amabilis/Vaccinium membranaceum/Xerophyllum tenax* and *Tsuga mertensiana/Vaccinium membranaceum* Associations from the Gifford Pinchot (Brockway et al. 1983) and Mt. Hood and Willamette National Forests (Hemstrom et al. 1982) are very comparable to the *Tsuga heterophylla* and *Tsuga mertensiana* phases, respectively, of our ABAM/XETE Association. The *Tsuga heterophylla-Abies amabilis/Xerophyllum tenax* Community Type of the Cedar River drainage (del Moral and Long 1977) appears similar to the *Tsuga heterophylla* phase of our ABAM/XETE but is too rich in coverage of shrubs other than *Vaccinium membranaceum* to be comfortably assigned to our *Tsuga heterophylla* phase. An ABAM/XETE Association has been described for the White River drainage (Henderson and Peter 1981) but probably does not occur beyond Snoqualmie Pass. Dyrness et al. (1974) identify comparable communities in the Oregon Cascade Range. They are again separated into two types—*Abies amabilis/Vaccinium membranaceum/Xerophyllum tenax* and *Abies amabilis-Tsuga mertensiana/Xerophyllum tenax*—which relate to the two *Tsuga* phases of our ABAM/XETE Association. Subalpine forests of *Abies lasiocarpa, Picea engelmannii*, and *Tsuga mertensiana* with *Vaccinium membranaceum/Xerophyllum tenax* understories are common in the Rocky Mountains of northern Idaho and western Montana (Daubenmire and Daubenmire 1968, Pfister et al. 1977). Comparable communities are apparently absent from the Olympic Mountains and British Columbia (Fonda and Bliss 1969, Krajina 1965).

Cold Forest Ecosystems

The last major group of five associations and one community type occupy relatively cold, snowy environments and are, therefore, most commonly found in the *Tsuga mertensiana* Zone. These subalpine forests are not exclusively high-elevation types, however; they may occur at moderate elevations (e.g., 1000 m or 3,500 ft) where topography creates areas of cold air drainage or accumulation. Tree data for this group of communities is presented in Table 9. Understory characteristics are presented in Table 10. The reader should recall that several associations discussed earlier (ABAM/XETE and ABAM/TIUN) can also be appropriately considered in this group and are included (for a second time) in Tables 9 and 10 to make comparisons easier.

Abies amabilis/Rubus lasiococcus Association

The *Abies amabilis/Rubus lasiococcus* Association (ABAM/RULA) encompasses three closely related vegetative types. There are two geo-

graphic phases: the wet, west-side *Erythronium montanum* phase, and the dry, east-side *Rubus lasiococcus* phase. In addition, a series of early successional stands have been recognized as an *Abies lasiocarpa/Valeriana sitchensis* Community Type. The *Erythronium montanum* phase of the ABAM/RULA Association appears to be the most extensive. All three groupings are similar in the sites occupied: at high elevations, often adjacent to meadow or parkland, often southerly exposed, and with modest to well-drained herb layers and a shrub layer largely confined to *Vaccinium membranaceum*.

Erythronium montanum Phase—The *Erythronium montanum* phase is found in the wetter two-thirds of the Park from the Carbon River drainage, counterclockwise through most of the Ohanapecosh River drainage, including the Three Lakes region. Elevations of the 24 sample plots range from 1320 to 1720 m (4,356 to 5,680 ft). Over three-fourths of the plots are on upper slopes or ridgetops, and most have southerly aspects. Soils are generally developed in tephras but range widely in morphology, from little profile development to strong horizonation.

Abies amabilis is the major tree species in mature stands of this association, sometimes forming essentially pure stands (Table 9). *Tsuga mertensiana* and *Chamaecyparis nootkatensis* are the most important associates. *Abies lasiocarpa* or *Abies procera* may be important in individual stands but not in the type as a whole. The only tree species reproducing in significant numbers is *Abies amabilis*.

The understory in the *Erythronium montanum* phase of the ABAM/RULA type is generally distinguished by its herbaceous layer (average cover 40 percent) (Fig. 28 and Table 10). The modest shrub layer (average cover 21 percent) consists mainly of *Vaccinium membranaceum*, although *Rhododendron albiflorum* is often present in small quantities (up to 10 percent coverage). The herbaceous layer is dominated by *Erythronium montanum* and *Rubus lasiococcus*. Other species with high presence are *Arnica latifolia*, *Rubus pedatus*, *Valeriana sitchensis*, *Viola sempervirens*, and *Veratrum viride*. Understory coverage varies widely and can be quite sparse in stands with dense overstories.

Young stands growing on the *Erythronium montanum* phase of the ABAM/RULA Habitat Type vary widely in composition and structure. Stands dominated by *Abies lasiocarpa* and by *Abies procera* have been encountered along with others dominated by *Abies amabilis* alone and in mixture with *Tsuga mertensiana* and *Chamaecyparis nootkatensis*. Chance probably places a major role in determining tree composition; in other words, seed availability at the time of disturbance. Elevation may play a role in segregating the two seral *Abies* spp., with *Abies procera* tending to capture lower elevation and *Abies lasiocarpa* higher elevation sites in this habitat type.

Table 9. Average tree density (stems per hectare) for the cold forest types by species and stem-diameter class, Mount Rainier National Park.

Type and species[1]	Con[2]	Basal area[3]	≤1[5] ≤1.4 m	≤1[5] >1.4 m	Stem-diameter class[4] 1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	>12
Abies amabilis/Rubus lasiococcus Association, *Rubus lasiococcus* Phase																
Abies amabilis	100	38.8	7,370	711	153	76	41	25	17	16	10	9	3	1	1	
Chamaecyparis nootkatensis	70	16.9	667	152	44	16	9	20	10	9	2	1	2	2		1
Tsuga heterophylla	52	8.0	96	43	12	7	7	5	3	2	2	1	2	1		1
Tsuga mertensiana	41	5.0	74	37	16	5	1	3	3		1	1	2			1
Pseudotsuga menziesii	26	12.5	7	14	2	5	6	3	3	3	5	1	1			3
Abies lasiocarpa	26	2.7	111	9	7	8	3	5	2	1						
Abies procera	15	1.8	15	16	18	14	6	1								
Picea engelmannii	11	1.1				1		1		1				1		
Thuja plicata	11	0.6	30	3	1								1			
Pinus monticola	4	0.0		1												
All species[6]		87.4	8,370	987	252	131	73	62	39	33	19	13	11	4	1	5
Abies amabilis/Rubus lasiococcus Association, *Erythronium montanum* Phase																
Abies amabilis	100	55.0	7,992	448	79	46	66	50	37	29	12	6	1	4	2	2
Tsuga mertensiana	87	24.5	267	50	18	27	28	14	12	4	6	4	3		1	4
Chamaecyparis nootkatensis	67	6.7	275	56	14	15	13	12	4	1		2				
Abies lasiocarpa	17	4.0	33	12	8	6	4	6	3	1	3					
Tsuga heterophylla	17	0.9	8	1					1	1	1					
Abies procera	8	2.4											1	2		
Pseudotsuga menziesii	4	1.1		1		1		1			1	1				
Pinus monticola	4	0.4									1					
Picea engelmannii	4	0.0				1										
All species[6]		95.1	8,575	567	119	96	112	83	57	36	23	13	5	6	3	5
Abies lasiocarpa/Valeriana sitchensis Community Type																
Abies lasiocarpa	100	54.6	1,190	386	200	166	172	60	29	16	7	1				
Abies amabilis	90	4.6	3,229	132	28	18	11	4	3			1				
Picea engelmanii	43	2.6	10	4	4	7	5	6	3							
Tsuga mertensiana	24	0.9		10	4	2	3	1		1						
Pseudotsuga menziesii	19	2.8		4		4		4	2	3	1					
Tsuga heterophylla	19	0.3	29	2			1	1								
Chamaecyparis nootkatensis	14	1.2	19	33	30	8	2									
Abies procera	10	0.6		1			1	1		1						
Pinus albicaulis	5	0.5						1	1							
All species[6]		68.1	4,476	572	266	206	195	79	38	21	8	2				
Abies amabilis/Menziesia ferruginea Association, Climax Phase																
Abies amabilis	100	43.2	13,080	924	125	57	38	39	36	20	8	7	2	4		
Chamaecyparis nootkatensis	80	12.0	210	23	4	3	6	8	8	5	4	2	2	2		
Tsuga heterophylla	75	19.9	1,160	89	12	6	7	9	6	1	8	6	2	1	1	3
Tsuga mertensiana	70	8.3	200	49	14	8	4		2	1	4	1	1	1	1	1
Pseudotsuga menziesii	25	7.6							1		1	1	1			3
Thuja plicata	10	0.0		6												
All species[6]		91.1	14,650	1,090	155	74	55	56	54	27	25	16	7	8	2	7
Abies amabilis/Menziesia ferruginea Association, Seral Phase																
Abies amabilis	100	19.8	8,229	1,533	350	73	21	26	4							
Tsuga heterophylla	100	14.4	486	572	74	48	45	6	3			3	3			
Tsuga mertensiana	86	1.7	143	139	48	12										
Chamaecyparis nootkatensis	57	3.1	143	331	100	9	3									

Table 9. Continued

Type and species[1]	Con[2]	Basal area[3]	≤1[5] ≤1.4 m	≤1[5] >1.4 m	Stem-diameter class[4] 1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	>12
Pseudotsuga menziesii	57	2.8		14	22		9	9								
Abies lasiocarpa	57	1.8	343	12	18		6	6								
Thuja plicata	57	1.4	57	54	11			7								
Pinus monticola	43	0.1		6	3											
Abies procera	29	5.1			30	7	22	7	4							
Picea engelmannii	14	0.5			7	7										
All species[6]		50.8	9,400	2,662	664	156	106	62	10			3	3			
Chamaecyparis nootkatensis/Vaccinium ovalifolium Association																
Chamaecyparis nootkatensis	100	35.4	1,400	63	27	42	59	43	24	7	6	5	3	3		2
Abies amabilis	100	30.4	7,613	628	153	54	25	22	16	9	7	4	1	2	1	1
Tsuga mertensiana	93	22.9	120	24	13	7	7	19	10	4	5	4	2	1	6	1
Tsuga heterophylla	67	6.9	533	134	16	12	8	1	3	4	3	1			1	
Picea engelmannii	7	2.6								4	3					
Abies procera	7	0.4								1						
Pinus monticola	7	0.1					1									
All species[6]		98.7	9,667	850	209	114	100	85	53	29	24	15	6	5	8	4
Abies amabilis/Rhododendron albiflorum Association																
Abies amabilis	100	34.5	9,936	619	71	42	59	38	26	12	9	2	3	1		1
Tsuga mertensiana	92	26.9	520	56	21	5	6	20	18	12	11	8	3	3	1	
Chamaecyparis nootkatensis	80	14.9	840	116	20	25	27	18	12	2	3	2	2		1	
Tsuga heterophylla	32	2.7	88	15		1		1	1	2	1	2				
Pseudotsuga menziesii	4	1.0									1		1			
Pinus monticola	4	0.6							1		1					
Abies procera	4	0.5										1				
Thuja plicata	4	0.0	56	11												
All species[6]		81.1	11,440	816	111	73	92	76	58	28	24	15	8	3	2	1

[1]Species are ordered within type by constancy.
[2]Constancy, expressed as percent of sample containing the species.
[3]Expressed as meters squared per hectare.
[4]Decimeters (dm) in diameter at breast height (1.4 m above the ground).
[5]The ≤1 dm diameter class is subdivided into two classes based on height.
[6]Column sums may not be exact due to rounding error.

Table 10. Constancy and characteristic cover of all shrub and herb taxa for the cold forest community types of Mount Rainier National Park.

	Community type[1]													
	15a. ABAM/RULA		15b. ABAM/RULA		16.		19a. ABAM/MEFE		19b. ABAM/MEFE		18.		17.	
Number of plots per type:	RULA phase 27		ERMO phase 24		ABLA2/ VASI 21		Climax phase 20		Seral phase 7		CHNO/ VAOV 15		ABAM/ RHAL 25	
Taxa	Con	Cov[2]	Con	Cov	Con	Cov	Con	Cov	Con	Cov	Con	Cov	Con	Cov
SHRUBS														
Sambucus spp.	4	28												
Virburnum edule	7	T												
Amelanchier alnifolia	4	3												
Rubus ursinus	4	T												
Taxus brevifolia	7	2												
Rubus parviflorus	4	T												
Acer circinatum	7	13												
Berberis nervosa	22	1					5	1			7	T		
Pachistima myrsinites	26	3			10	1			29	1			4	T
Chimaphila umbellata	33	1			5	T	5	T			7	T	8	T
Vaccinium deliciosum	4	30	33	1	38	11							8	5
Ribes spp.	7	2			19	T							4	T
Rosa gymnocarpa	4	3							14	1				
Gaultheria shallon					5	T								
Ribes howellii			4	1	5	4	5	T						
Vaccinium scoparium	11	1	13	T	57	8					7	T	8	T
Ribes lacustre	7	T			5	T					13	2		
Vaccinium membranaceum	100	21	100	17	76	17	95	11	86	23	100	5	100	15
Rubus lasiococcus	96	6	88	7	86	22	95	2	86	4	100	4	96	4
Chimaphila menziesii	19	T	4	T	5	T			14	T	27	T	8	T
Vaccinium parvifolium	7	1					20	T			7	1	4	T
Sorbus sitchensis	37	T	58	1	48	1	65	1	43	T	40	1	68	1
Gaultheria humifusa	7	T			5	T					13	1	4	T
Gaultheria ovatifolia	11	T			5	T	10	3	71	2	13	2	4	T
Alnus sinuata	7	2							29	33	7	10	4	T
Cornus canadensis	11	1					10	T	29	4	20	2	4	2
Ribes bracteosum					5	10	5	T			7	T		
Rubus pedatus	52	1	58	4	19	3	90	5	43	3	100	14	96	7
Rhododendron albiflorum	37	5	71	3	10	8	50	3	71	8	80	5	100	33
Vaccinium ovalifolium	37	3	50	3	5	T	95	8	86	13	100	18	88	9
Vaccinium alaskaense	11	4	17	T	5	2	50	15	71	13	67	5	24	34
Menziesia ferruginea	26	2	29	1	5	T	100	15	100	24	100	6	72	13
Rubus spectabilis							10	T	29	1	13	T	4	T
Oplopanax horridum							5	T			13	T		
Phyllodoce empetriformis			8	1							7	T	24	1
Salix scouleriana											27	4		
Holodiscus discolor													4	T
HERBS														
Smilacina racemosa	4	T												
Pyrola virens	4	T												
Pyrola picta	4	T												
Carex rossii	4	T												
Festuca subulata	4	1												
Actaea rubra	4	T												
Allotropa virgata	4	T	4	T										
Hypopitys monotropa	4	T			5	T								
Gilia spp.	4	2			5	T								
Daucus spp.			4	T										
Nothochelone nemorosa	26	T	4	T	14	T	5	1			7	T		

Table 10. Continued

	Community type[1]													
	15a. ABAM/RULA		15b. ABAM/RULA		16.		19a. ABAM/MEFE		19b. ABAM/MEFE		18.		17.	
Number of plots per type:	RULA phase 27		ERMO phase 24		ABLA2/ VASI 21		Climax phase 20		Seral phase 7		CHNO/ VAOV 15		ABAM/ RHAL 25	
Taxa	Con	Cov[2]	Con	Cov	Con	Cov	Con	Cov	Con	Cov	Con	Cov	Con	Cov
Hieracium albiflorum	30	T			19	1					13	T		
Galium oreganum	4	T			10	3								
Polemonium spp.	7	T			24	1								
Polemonium pulcherrimum	11	T			38	1								
Castilleja spp.	4	T			14	1								
Smilacina stellata	22	1			10	2	10	1	29	1				
Festuca occidentalis			4	60	5	T								
Ranunculus spp.			4	T	5	T								
Lupinus latifolius	15	2	21	2	62	2			14	1				
Anemone deltoidea	4	1			19	T								
Bromus vulgaris	11	1	4	T	33	1							4	T
Pedicularis racemosa	22	T	17	T	43	T					7	T	8	T
Epilobium angustifolium	15	T	4	T	19	T			14	1	13	T		
Poa nervosa					5	T								
Gnaphalium spp.					5	T								
Micromeria spp.					5	T								
Ligusticum spp.					5	T								
Pedicularis spp.					5	4								
Geum spp.					5	T								
Luina stricta					5	1								
Arnica latifolia	48	3	29	1	81	6	25	T	29	T	47	3	20	1
Lilium columbianum	4	T			14	T	5	T			7	T		
Luzula parviflora	22	2	29	1	43	16	10	T	14	T	40	1	8	T
Fragaria vesca	4	2			14	1			29	1				
Anemone lyallii	4	1			5	T					7	T		
Arenaria macrophylla	4	1			19	1							4	T
Valeriana sitchensis	56	2	50	2	86	13	25	1	29	T	67	4	28	T
Ligusticum grayi	4	T	33	T	52	1	5	T			33	T	4	T
Viola sempervirens	59	1	38	1	67	2	45	T	71	1	47	2	28	1
Luzula glabrata			13	1	33	7							8	T
Veratrum viride	26	T	46	1	90	1	10	T	43	T	47	1	20	T
Achlys triphylla	37	3			19	4	25	3	43	2	40	6	4	25
Adenocaulon bicolor			4	T	5	T	5	T	14	T				
Trillium ovatum	30	T	8	T	33	1	40	T	43	T	47	T	4	T
Tiarella trifoliata	11	T	8	1			15	T			27	T		
Clintonia uniflora	52	2	8	3	33	11	60	2	57	3	53	3	16	4
Listera borealis	22	1			5	20	5	3	43	2	13	1	8	T
Senecio triangularis	4	T	8	T			5	1			7	T	4	T
Goodyera oblongifolia	56	T	13	T	5	T	45	T	29	1	53	T	28	T
Pyrola asarifolia	11	1							29	T	7	T	4	T
Polygonum bistortoides					14	T					7	T		
Galium triflorum	4	T			5	T			14	T	7	T		
Xerophyllum tenax	48	2	33	5	43	11	50	4	86	9	33	1	44	2
Pyrola secunda	81	1	29	1	33	2	85	1	43	T	73	1	60	1
Mitella spp.	22	2	29	1	48	1	5	T			53	1	28	1
Corallorhiza spp.	15	T	8	T			25	T			27	T	8	T
Viola glabella	11	1	8	T	33	5	15	T			53	6	4	T
Tiarella unifoliata	33	2	33	1	19	1	55	1	57	T	100	7	16	1
Saxifraga spp.							10	1						
Polystichum lonchitis			4	T							7	T		
Polystichum munitum	7	T			5	2			29	T	7	T	4	T
Osmorhiza spp.	7	T	21	1	19	2					67	1		

Table 10. Continued

	Community type[1]													
	15a. ABAM/RULA		15b. ABAM/RULA		16.		19a. ABAM/MEFE		19b. ABAM/MEFE		18.		17.	
Number of plots per type:	RULA phase 27		ERMO phase 24		ABLA2/ VASI 21		Climax phase 20		Seral phase 7		CHNO/ VAOV 15		ABAM/ RHAL 25	
Taxa	Con	Cov[2]	Con	Cov	Con	Cov	Con	Cov	Con	Cov	Con	Cov	Con	Cov
Luetkea pectinata	4	2											4	2
Dodecatheon spp.			4	T							7	T		
Lathyrus spp.							5	T						
Streptopus roseus	26	3	21	1	19	4	45	2	43	T	80	5	16	1
Erythronium montanum	22	6	96	24	43	4	25	5	29	T	80	10	80	19
Anaphalis margaritacea					5	T			29	2				
Mertensia spp.					10	T							4	T
Carex spp.	4	T	4	T	24	T	5	T	14	T	27	1	8	1
Streptopus streptopoides			8	T			20	T			27	T		
Lithospermum californicum	26	T	17	T	24	T	20	T	29	T	53	1	48	T
Carex mertensii					5	4					7	1		
Lycopodium clavatum			8	T							13	3	4	T
Athyrium filix-femina			17	T			5	T	14	T	33	1	8	1
Corallorhiza maculata			4	T			5	T			7	T	4	T
Blechnum spicant	4	3	8	T			15	T	14	T	47	T	8	T
Listera cordata	11	T	4	T	5	T	40	T	14	T	93	T	16	T
Pteridium aquilinum									57	4				
Dryopteris austriaca							5	1			7	T		
Corallorhiza mertensiana							5	T			7	T		

Taxa	15a Con	15a Cov	15b Con	15b Cov	16 Con	16 Cov	19a Con	19a Cov	19b Con	19b Cov	18 Con	18 Cov	17 Con	17 Cov
Agrostis spp.									14	T				
Habenaria saccata			4	T			10	T			40	T		
Streptopus amplexifolius					5	T	10	T			40	1		
Habenaria orbiculata							5	T			13	T		
Montia spp.							5	T			20	1		
Gymnocarpium dryopteris							10	3	29	T	60	4		
Trautvetteria grandis				4	T			5	3			33	2	83
Pyrola uniflora							5	T			7	T	4	T
Caltha biflora							5	T			7	2	4	2
Stipa occidentalis											7	T		
Trifolium latifolium											7	2		
Equisetum fluviatile											20	5		
Dicentra formosa											7	1		
Oxalis oregana											7	2		
Veronica spp.													4	2
Lupinus albicaulis													4	T
Average total shrub cover[3]	30		21		24		44		81		39		72	
Average total herb cover[4]	21		40		65		16		23		59		31	

[1]Community type names and numbers correspond with those in Table 1.
[2]Constancy (Con) is the percent occurrence of a species in the plots assigned to each forest type. Characteristic cover (Cov) is the average cover of a species computed by averaging over only those plots where it occurs. Values are rounded to nearest percent. Values less than 0.5% are denoted by 'T.'
[3]Average total shrub cover is computed by summing the shrub cover on each plot, then averaging those totals over all plots in a type.
[4]Average total herb cover is computed by summing the herb cover on each plot, then averaging those totals over all plots in a type.

Figure 28. The understory in the *Erythronium montanum* phase of the *Abies amabilis/ Rubus lasiococcus* is characterized by *Erythronium montanum* and *Vaccinium membranaceum*.

The *Erythronium montanum* phase is closely related to the *Rubus lasiococcus* phase of the ABAM/RULA Association. The *Erythronium montanum* phase occupies the wetter portions of the Park. The two phases are distinguished by the importance of *Erythronium montanum* as well as a number of minor shifts in importance and occurrence of other species, but floristic intergradation between the phases is also found in some stands (for example, in plot 490).

Rubus lasiococcus Phase—The *Rubus lasiococcus* phase is essentially confined to the White River and northeastern Ohanapecosh River drainages. All but three of the 27 sample plots are on southerly and easterly exposed (aspects 45° to 240°) mountain slopes and ridgetops at elevations of 1270 to 1740 m (4,190 to 5,740 ft). Soils are developed in tephra or colluvial deposits.

Abies amabilis is the major overstory tree species in mature stands but has *Chamaecyparis nootkatensis* and scattered veteran *Pseudotsuga*

menziesii as major associates (Table 9). *Abies amabilis* makes up 88 percent of the reproduction, with *Chamaecyparis* making up most (8 percent) of the remainder.

Herb or shrub layers are not well developed in mature stands in the *Rubus lasiococcus* phase (Table 10). The shrub cover (average 30 percent) is strongly dominated by *Vaccinium membranaceum*. The herbaceous layer (average cover 21 percent) has *Rubus lasiococcus, Pyrola secunda, Arnica latifolia, Valeriana sitchensis*, and *Clintonia uniflora* as the most important components. *Erythronium montanum* is absent or has cover not over 2 percent (plot 490 is an intergrade phase whose herb complement is dominated by both *Erythronium montanum* and *Rubus lasiococcus*).

Many young stands of the *Rubus lasiococcus* phase, particularly at higher elevations, are dominated by *Abies lasiocarpa*. We assigned most of these stands to the *Abies lasiocarpa/Valeriana sitchensis* community type. At lower elevations within this phase, young stands may be dominated or codominated by *Abies procera*. In both this and the *Erythronium montanum* phase, herbaceous cover tends to be greater in young than in mature stands.

Other associations closely related to both phases of the *Abies amabilis/Rubus lasiococcus* are the ABAM/TIUN, ABAM/XETE, and *Abies amabilis/Rhododendron albiflorum*. At the boundary of its lower elevation the ABAM/RULA type grades into the strongly herb-dominated ABAM/TIUN type. Modal forests of these two types are easily distinguished. There is, for example, a much more diverse and luxuriant herb layer, general absence of *Erythronium*, and replacement of *Tsuga mertensiana* by *Tsuga heterophylla* in ABAM/TIUN stands, as well as a sparsity of *Tiarella unifoliata* on the ABAM/RULA type. Floristic and environmental intergrades occur between the two associations and may make a site difficult to classify, however. The *Abies amabilis/Rhododendron albiflorum* type has a shrub layer that is much denser and richer in species than occurs on the *Erythronium montanum* phase of the ABAM/RULA Association. The ABAM/XETE Association is distinguished from ABAM/RULA by the dominance of *Xerophyllum tenax* and sparsity of other herbs. Only 2 stands of 50 in the ABAM/RULA Association had *Xerophyllum* cover of over 6 percent. The ABAM/XETE sites are warmer and drier than those of ABAM/RULA, which are, in turn, warmer and drier than those of the *Abies amabilis/Rhododendron albiflorum* and *Abies amabilis/Menziesia ferruginea* habitat types.

This habitat type presents no major management problems. The forests are attractive to visitors because they occupy warmer exposures and lack the heavy shrub cover and saturated soils of the north slope and bench forests within the *Tsuga mertensiana* Zone.

Franklin's (1966) *Abies amabilis/Veratrum viride* Association of the southern Washington and northern Oregon Cascade Range is similar to our ABAM/RULA type. Most of Franklin's plots were actually in seral *Abies lasiocarpa* stands assignable to the *Abies lasiocarpa/Valeriana sitchensis* Community Type, however. The *Abies amabilis/Vaccinium membranaceum/Clintonia uniflora* Associations from the Gifford Pinchot, Mt. Hood, and Willamette National Forests appear closely related (Brockway et al. 1983, Hemstrom et al. 1982). The relationships between our ABAM/RULA Association and types to the north of the Park are currently confused. In his work on the Mt. Baker-Snoqualmie National Forest, Henderson (see, e.g., Henderson and Peter 1981) created *Tsuga mertensiana/Vaccinium membranaceum* and *Abies amabilis/Vaccinium membranaceum* Associations which include elements of our ABAM/RULA type, but thorough comparisons must await availability of detailed stand data. Fonda and Bliss' (1969) *Abies amabilis-Tsuga mertensiana* type appears to be an Olympic Mountain relative of the *Erythronium montanum* phase.

***Abies lasiocarpa/Valeriana sitchensis* Community Type**

Pure or nearly pure *Abies lasiocarpa* forests dominate warm, southerly slopes at high elevations in the White and Ohanapecosh River drainages. These young stands (often 100–200 years old) are similar in structure and composition and distinctive enough to be distinguished as the *Abies lasiocarpa/Valeriana sitchensis* Community Type (ABLA2/VASI). We interpret this community type as an early vegetation stage within environments of the ABAM/RULA Habitat Type.

The elevations of the 21 stands sampled in this community ranged from 1450 to 1860 m (4,780 to 6,140 ft), with the aspects generally southerly (average 187°, ranging from 112 to 308°). The topography often consisted of upper slopes or ridges, and the soils consisted of tephra and colluvial parent materials.

Abies lasiocarpa dominates this community (Fig. 29); *Pseudotsuga menziesii* and *Abies amabilis* are the most consistent associates, although *Abies procera, Tsuga mertensiana*, and *Picea engelmannii* can all be important in individual stands (Table 9). *Abies amabilis* invariably dominates the seedling and, generally, the sapling size classes as well; we hypothesize the gradual replacement of *Abies lasiocarpa* by *Abies amabilis* as the forests mature.

The understory has a luxuriant layer of herbs (average cover 65 percent) and a modest shrub layer (average cover 24 percent) composed mainly of *Vaccinium membranaceum* (Table 10); *Vaccinium scoparium* or *V. deliciosum* or both also appear in most stands. Major herbs are *Rubus lasiococcus, Valeriana sitchensis, Arnica latifolia, Viola sempervirens, Polemonium pulcherrimum*, two species of *Luzula, Veratrum viride, Mitella* spp., *Viola glabella, Clintonia uniflora*, and *Pedicularis*

Figure 29. Representative stand belonging to the *Abies lasiocarpa/Valeriana sitchensis* community type; dominants are *Abies lasiocarpa* and *Vaccinium membranaceum* in the tree and shrub layers, respectively.

racemosa. This community is often adjacent to meadows, and understories reflect this influence with frequent occurrence of species such as *Senecio triangularis* and *Ligusticum grayi*.

The ABLA2/VASI type is an attractive and important community type on Sunrise Ridge, at Grand Park, and along the crest of the Cascade Range. It occupies much of the forest-parkland ecotone in these areas, making it important to visitors and wildlife. Fire danger in this type is among the highest of any in the Park (Hemstrom 1982) because of the frequency of lightning strikes, its location in the driest part of the Park, and abundance of continuous highly flammable fuels represented by the limby, resinous *Abies lasiocarpa*. It is only moderately resilient to visitor impacts but may be suitable for back-country campsites.

This community type has strong affinities with the many *Abies lasiocarpa* communities found along the east slope of the Cascade Range and in the northern Rocky Mountains (Pfister et al. 1977). At Mount Rainier, *Abies lasiocarpa* is usually subject to replacement by *Abies amabilis*, making the community type seral (Franklin and

Mitchell 1967). Franklin (1966) noted similar stands as far south as the east slopes of Mount Hood (see his *Abies amabilis/Veratrum viride* Association). Thornburgh (1969) noted that *Abies lasiocarpa* dominated stands on high south slopes near the southwest corner of Mount Rainier (High Rock). Stands of the ABLA2/VASI Community Type do occur on the west side of the Park, within the *Erythronium montanum* phase of the ABAM/RULA Habitat Type, but are less common than on the east side. This could be due to a variety of factors, including less frequent fires and greater competition from associated species on the moister west side. We have noted comparable stands in the Glacier Peak and Goat Rocks Wilderness areas. Fonda and Bliss (1969) describe similar stands in the northeast corner of Olympic National Park.

***Abies amabilis/Menziesia ferruginea* Association**

The *Abies amabilis/Menziesia ferruginea* Association (ABAM/MEFE) is a common, shrub-dominated, mid elevation to high elevation type found throughout Mount Rainier National Park. It occupies relatively cool, moist sites in the upper *Abies amabilis* and lower *Tsuga mertensiana* Zones where snowpacks are moderate to heavy. All aspects and landforms are represented in the 27 sample plots, although northerly aspects and mountain slopes and benches are the most common sites. Plot elevations range from 1080 to 1500 m (3,560 to 4,950 ft). Tephra soils with minimal or weak iron-pan development are most common.

Mature forests are dominated by *Abies amabilis*, which also makes up 88 percent of the seedlings and 70 percent of the saplings (Table 9). Either *Tsuga mertensiana* or *Tsuga heterophylla* can be the major hemlock associate, although the latter is the most abundant and both are often present. *Chamaecyparis nootkatensis* is present in about 75 percent of the plots and can be an important dominant. All other tree species are minor.

The understory generally has a well-developed shrub layer (Fig. 30) (average cover 44 percent) and a modest herb layer (average cover 16 percent) (Table 10). Major shrubs are, in order of appearance, *Menziesia ferruginea, Vaccinium membranaceum, V. ovalifolium, V. alaskaense*, and *Rhododendron albiflorum* (Table 9). The most important herbaceous species are *Rubus pedatus, R. lasiococcus, Xerophyllum tenax, Pyrola secunda, Clintonia uniflora*, and *Streptopus roseus*. Average cover is low for all six species (less than 4 percent). Only *Rubus lasiococcus* has high presence, occurring in more than 90 percent of the stands. *Erythronium montanum* has low presence but may be abundant when it does occur (up to 10 percent cover).

Seven young forests were analyzed separately. Tree diversity is much greater in young than in old stands (Table 9). *Abies amabilis* and *Tsuga heterophylla* are still dominant, but *Abies lasiocarpa, Abies procera, Pseudotsuga menziesii*, and *Thuja plicata* all share the role of major

Figure 30. Representative mature stand on *Abies amabilis/Menziesia ferruginea* habitat type.

associates in one or more stands with *Tsuga mertensiana* and *Chamaecyparis nootkatensis*. Shrub cover (average 81 percent) is much greater in young than in mature stands. The five shrub species listed for mature stands are still dominants, but *Alnus sinuata* is an important addition in some stands. Differences in the herb layer appear minor except for the addition of *Pteridium aquilinum*.

Its extent makes the ABAM/MEFE an important association within the Park. It is indicative of moderate snowpack levels and moist but not waterlogged sites; hence, management constraints are fewer than on the environmentally more severe *Abies amabilis/Rhododendron albiflorum* sites. The ABAM/MEFE type is not the best choice for site development, however, in terms of length of growing season and soil drainage, although the vegetation is typically dense and resilient.

Both the *Abies amabilis/Rhododendron albiflorum* and ABAM/VAAL Associations are closely related to the ABAM/MEFE type. There is a much greater abundance of *Rhododendron albiflorum* and *Chamaecyparis nootkatensis* in the *Abies amabilis/Rhododendron albiflorum* than in the ABAM/MEFE type. The regular occurrence of *Tsuga heterophylla* in the ABAM/MEFE Association is a feature that

suggests more favorable temperatures and snowpack than in the *Abies amabilis/Rhododendron albiflorum* Association. The ABAM/MEFE can be distinguished from the ABAM/VAAL type by a variety of features including the regular occurrence of *Tsuga mertensiana, Chamaecyparis nootkatensis*, and *Menziesia ferruginea* and sparsity of many ABAM/VAAL indicators such as *Pseudotsuga menziesii, Cornus canadensis*, and even *Vaccinium alaskaense*.

Similar associations have been reported from adjacent portions of the Cascade Range. Franklin (1966) recognized an *Abies amabilis/Menziesia ferruginea* Association in the southern Washington Cascade Range. Floristically this association is very similar to ours. Mountain hemlock is more common than western hemlock in Franklin's type, although ". . . this is the only association where extensive mixing of the two hemlocks was encountered . . .," a situation comparable to the ABAM/MEFE type at Mount Rainier. He also considered this type to be at the transition between the *Tsuga mertensiana* and *Abies amabilis* zones. The *Abies amabilis/Menziesia ferruginea* Association described for the Gifford Pinchot (Brockway et al. 1983) and Mt. Hood and Willamette (Hemstrom et al. 1982) National Forests are very similar to our association. *Chamaecyparis nootkatensis* and *Rhododendron albiflorum* are generally important and herbs are generally of lesser importance at Mount Rainier than in associations to the south. The relationship between our ABAM/MEFE Association and communities to the north is currently confused. Although Henderson and Peter (1981) report an ABAM/MEFE Association in the White River drainage, it was not common and is not reported from more northerly locales (see, e.g., Henderson and Peter 1985). The type may either be absent or have been partitioned into other associations. The *Abies amabilis-Tsuga heterophylla/Vaccinium membranaceum* and *Abies amabilis/Vaccinium membranaceum-Vaccinium ovalifolium* community types described by del Moral and Long (1977) from the Cedar River drainage have similarities to our ABAM/MEFE, although it is difficult to tell from the data presented; their two community types were separated primarily by the abundance of *Tsuga heterophylla*, a characteristic which we view as being of minor importance on this habitat type.

Similar subalpine forest communities, minus *Abies amabilis*, have been described from the northern Rocky Mountains. The *Tsuga mertensiana/Menziesia ferruginea* and *Abies lasiocarpa* habitat types of Daubenmire and Daubenmire (1968) and of Pfister et al. (1977) are the best examples.

Chamaecyparis nootkatensis/Vaccinium ovalifolium Association

The *Chamaecyparis nootkatensis/Vaccinium ovalifolium* Association (CHNO/VAOV) occurs on wet, often nearly swampy sites in the upper *Abies amabilis* and lower *Tsuga mertensiana* Zones throughout the

Park. Wet benches, draws, and lower slopes are typical landforms occupied by this relatively uncommon habitat type. Elevational range of the 15 sample plots is from 1170 to 1470 m (3,860 to 4,850 ft). The type can occur on any aspect, although most plots have northerly aspects. Soils develop in parent materials of tephra, alluvium, and colluvium. Deep organic surface horizons, high water tables, gleyed subsoils, and strong iron pans are common.

Chamaecyparis nootkatensis and *Abies amabilis* dominate mature forests, with *Tsuga mertensiana, Tsuga heterophylla*, or both as important associates (Table 9). *Picea engelmannii* may be present where cold air flows down valley drainages. *Abies amabilis* dominates the reproduction and is apparently the major climax tree species. Reproduction of *Chamaecyparis nootkatensis* is also abundant, however, with numbers approaching those of *Abies amabilis* in a few cases; this suggests that *Chamaecyparis nootkatensis* will also be at least a minor climax species. In fact, its maximum occurrence in the Park is on CHNO/VAOV habitats, based on abundance in all size classes and on total basal area.

The understory has a relatively rich and luxuriant herbaceous layer (Table 10). Shrub cover averages 39 percent but has a wide range of 10 to 65 percent. Major shrubs are *Vaccinium ovalifolium, Menziesia ferruginea, Vaccinium membranaceum*, and *Rhododendron albiflorum*. The distinctive compositional features are in the herb layer (average cover 59 percent). Typical dominants occurring in over half the plots are *Rubus pedatus, Rubus lasiococcus, Tiarella unifoliata, Streptopus roseus, Viola glabella, Erythronium montanum, Valeriana sitchensis, Gymnocarpium dryopteris*, and *Clintonia uniflora*. The nearly swampy nature of this association is even more sharply characterized by several "wetland" species which have, however, relatively low presence and importance values: *Mitella* spp., *Trautvetteria caroliniensis, Parnassia fimbriata*, and *Stenanthium occidentale* are good examples.

No young stands were sampled on this habitat type. Immature stands should closely resemble mature stands in composition, however. Shrub cover would be relatively high in early successional stages and would include species such as *Salix scouleriana* and *Alnus sinuata*. Forest stand development might be slow due to heavy competition from herbs and shrubs.

Special features of this association include the diversity of wetland species and maximal densities of *Chamaecyparis nootkatensis* as a forest component. It is obviously a poor environment for trails and totally unsuited for development of campsites. The wet soils and numerous springs, seeps, and streams would make trail construction expensive and maintenance a continuous problem. This habitat type is often associated with natural openings (wet meadows, fens, bogs, and ponds). Shrub thickets of *Alnus sinuata, Salix* spp., and *Spirea* spp. often occur at these ecotones between forest and fen. The association of this habitat

type with streams, ponds, and springs makes it rich in wildlife—birds, mammals, and especially amphibians.

The most clearly related habitat types in the Park are *Abies amabilis/Rhododendron albiflorum* and ABAM/OPHO. The former is generally on slopes at higher elevations, has much heavier shrub cover in which *Rhododendron albiflorum* is always present, and has a less diverse, less prolific herbaceous layer. The *Abies amabilis/Rhododendron albiflorum* Association probably experiences deeper snowpacks and colder temperatures than the CHNO/VAOV type, although frequent cold air accumulations are to be expected in the benches and terraces occupied by the CHNO/VAOV Association. The abundance of *Chamaecyparis nootkatensis*, *Vaccinium* spp.-dominated shrub layer, and general absence or sparsity of several key indicator species (for example, *Oplopanax horridum*, *Athyrium filix-femina*, and *Ribes lacustre*) distinguish CHNO/VAOV from the ABAM/OPHO Associations. Both air and soil drainage appear more rapid on ABAM/OPHO than CHNO/VAOV habitats, and productivity is correspondingly greater due to warmer temperatures and more aerobic soil environments.

Forest communities similar to the CHNO/VAOV Association have not been described from other parts of the Pacific Northwest. If the area of this habitat type is as limited in other locales as it is at Mount Rainier, other plant ecologists may have encountered it but chose to ignore it or treat it as an ecotone or minor edaphic type.

Abies amabilis/Rhododendron albiflorum Association

The *Abies amabilis/Rhododendron albiflorum* Association (ABAM/RHAL) is a shrubby, high-elevation environment of cool, wet slopes and benches found throughout the Park. Many stands occupy northerly aspects, although the type also occurs on some wet southerly aspects. Plot elevations range from 1210 to 1730 m (4,000 to 5,710 ft). Soils are generally podzolic with gleyed subsoils and iron pans, indicating high water tables and saturated conditions for most of the year. The association occupies a very cold and wet forest environment with a heavy snowpack (5 m or more) that lasts well into the summer; the growing season is, consequently, very short.

Mature forests are characteristically codominated by *Abies amabilis*, *Tsuga mertensiana*, and *Chamaecyparis nootkatensis* (Table 9). *Tsuga heterophylla*, *Pseudotsuga menziesii*, *Abies procera*, and *Pinus monticola* may occur but are minor components. Tree reproduction is strongly dominated by *Abies amabilis* with over 1,500 seedlings and saplings per hectare (600/acre). *Abies amabilis* constitutes 87 percent of the tree reproduction, with *Chamaecyparis nootkatensis* at 8 percent and *Tsuga mertensiana* at 4 percent.

The understory is a dense tangle of shrubs (Fig. 31) (total cover 72 percent) with scattered herbs (total cover 31 percent) (Table 10).

Rhododendron albiflorum, *Vaccinium membranaceum*, *Vaccinium ovalifolium*, and *Menziesia ferruginea* are the constant shrub dominants and cumulatively provide 90 percent of the shrub cover. Three common herbs (*Erythronium montanum*, *Rubus lasiococcus*, and *Rubus pedatus*) provide about 80 percent of the herbaceous cover. Some of the occasional minor herbs include *Listera caurina*, *Pyrola secunda*, *Xerophyllum tenax*, *Achlys triphylla*, and *Clintonia uniflora*.

Figure 31. Mature stand of *Abies amabilis*, *Tsuga mertensiana*, and *Chamaecyparis nootkakensis* on *Abies amabilis/Rhododendron albiflorum* habitat type; the dense tangle of tall shrubs is characteristic.

The few young stands sampled on this habitat type closely resemble the mature stands floristically. Shrub cover is typically very high until tree canopies close, and this may take a century or more due to low reproductive success. Shrub competition and the severe environment, with a very heavy, persistent snowpack, are both major deterrents to tree reproduction.

The key management aspects of this habitat type relate to its severe environment—a heavy, persistent snowpack; short, cool growing season; and soils with high water tables. Productivity is limited, trees do not attain large sizes, and, as indicated, new stands develop slowly following disturbance. Managers should avoid putting developments, including trails and back-country campsites, in this habitat type whenever possible.

The relationship between the ABAM/RHAL and ABAM/MEFE Associations is so strong that we considered making both part of a somewhat broader, high elevation association. The former occupies, on the average, higher elevations and admits less *Tsuga heterophylla* and more *Tsuga mertensiana* in the tree complement. Reasons for the shift in dominance between *Rhododendron albiflorum* and *Menziesia ferruginea* in these two associations are not clear. In addition, several stands on the undulating topography of higher elevations in the Park are not easily assignable to one or the other of these associations. Until high-elevation forest ecology in the Park is studied further, however, we prefer to hypothesize the distinctness of the ABAM/RHAL and ABAM/MEFE Associations.

The ABAM/RHAL and CHNO/VAOV Associations are obviously closely related environmentally. CHNO/VAOV occupies sites that are wetter and colder (by cold air convection) than the ABAM/RHAL.

Forests similar to ABAM/RHAL have been reported from adjacent portions of the Washington Cascade Range. Franklin's (1966) *Chamaecyparis nootkatensis/Rhododendron albiflorum* association is very similar, as are the *Tsuga mertensiana/Rhododendron albiflorum* (Brockway et al. 1983) and *Abies amabilis/Rhododendron albiflorum/ Clintonia uniflora* (Hemstrom et al. 1982) Associations. Henderson and Peter (1981) refer to their White River association as the *Tsuga mertensiana/Rhododendron albiflorum* type; it appears to become more varied in the northern Cascades (Henderson and Peter 1985). The use of three tree species in these association's names reflects varying preferences among the reproducing (and presumably climax) tree species.

Other Forest Communities

Several other forest types at Mount Rainier represent very specialized habitats of limited extent. Examples include: pioneering forest stands invading recently exposed glacial till, river alluvium, or lahar surfaces; talus slopes with a scattered forest cover; and swamp forests.

Pseudotsuga menziesii/Arctostaphylos uva-ursi Association

The *Pseudotsuga menziesii/Arctostaphylos uva-ursi* Association (PSME/ARUV) is extremely limited at Mount Rainier. Only two stands were sampled—on an outwash along the White River (Plate 1) and on a lahar surface near the west end of the Longmire campground. Alone, these two stands would be insufficient for recognizing an association; however, similar communities have been described (Franklin 1966) on lava flows, glacial outwash, and young pyroclastic flows in southern Washington and northern Oregon.

Stands in PSME/ARUV habitats are open, low in stature, and distinctive in composition (Fig. 32). Either *Pseudotsuga menziesii* or *Pinus contorta* may dominate, but almost any other indigenous tree species can be present provided a seed source is available. For example, both *Abies lasiocarpa* and *Chamaecyparis nootkatensis* occur in the Longmire stand, which is at about 800 m (2,640 ft).

Figure 32. Low stature forest dominated by *Pinus contorta* and *Pseudotsuga menziesii* on *Pseudotsuga menziesii/Arctostaphylos uva-ursi* habitat type along the Nisqually River; such sites are typically low in productivity but with a rich and distinctive ground cover of mosses, lichens, *Juniperus communis*, and *Arctostaphylos uva-ursi*.

The understory is low in stature but distinctive in composition. Major vascular plants are *Juniperis communis* and *Arctostaphylos uva-ursi*. There is a nearly complete ground cover of mosses and lichens in which *Rhacomitrium canescens* var. *ericoides* is the major component.

The vegetation on these sites is very hardy and, with the exception of the moss and lichen ground cover, will tolerate heavy use. Root systems are well protected by the rocky surface. Tree growth is very slow, and continuing mortality is apparent in the stands. These are interesting sites because of the high diversity of tree species often present and the distinctive ground plants.

As mentioned, similar forests have been described from a variety of substrates in the southern Washington and northern Oregon Cascade Range. *Pinus contorta* is probably the most common tree dominant, but *Pseudotsuga menziesii* is typically present and may be a climax species.

Swamp Forests

Swamp forests are open stands of stunted conifers or hardwoods occurring in localized wetlands (Fig. 33). Such sites are not extensive and often occur as ecotones between forests and marshes or ponds. At low to moderate elevations, *Thuja plicata, Pinus monticola, Tsuga heterophylla*, and *Alnus rubra* are the species most likely to be associated with wetlands. The scattered trees are typically associated with *Lysichitum americanum, Carex* spp. (especially *Carex obnupta*), and ferns as herbaceous dominants. *Lysichitum* and other wetland herbs may also occur in small stands within a forest matrix on seasonally ponded habitats. Shrub associates on the wetlands include *Salix* spp., *Spiraea* spp., and *Alnus sinuata*. Swamps at higher elevations are similar but have *Chamaecyparis nootkatensis, Tsuga mertensiana, Pinus monticola, Picea engelmannii*, and *Abies amabilis* as constituent tree species.

Moraine Forests

Moraine forests have been studied by Sigafoos and Hendricks (1972) for the purpose of dating glacial activities. Our plots 350 and 484 occur on morainal debris of the Tahoma and Emmons glaciers. Soils of these cobbly rubbles are undeveloped. Sapling or pole-sized trees, often as thickets, include *Abies amabilis, A. lasiocarpa, Tsuga heterophylla, T. mertensiana*, and—particularly on the Emmons moraine—*Pinus contorta* and *Picea engelmannii*. The common shrub is *Alnus sinuata*, and herbs are almost nonexistent. Moraine forests are particularly conspicuous at Moraine Park. Here tree thickets thrive on lateral moraines of the Carbon Glacier with herbaceous meadows on fine-textured soils of the intermorainal landscape.

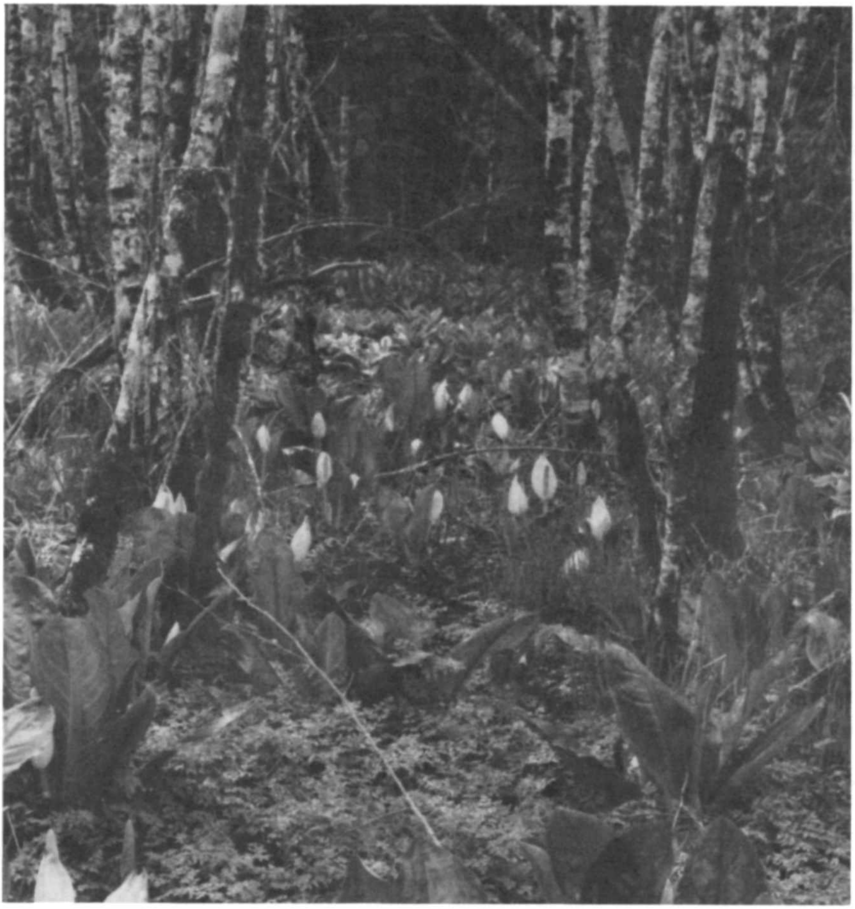

Figure 33. *Lysichitum americanum* is indicative of the wettest forested habitats or swamps; here it forms a stand in a seasonally-ponded depression within a forest matrix (Silver Falls loop trail, Ohanapecosh drainage).

Additional Forest Types

Pinus albicaulis sometimes fringes forests at timberline. More often this species occupies a seral role in subalpine parklands (Franklin and Mitchell 1967). An interesting dwarf forest of *Pinus albicaulis* with *Juniperis communis* can be found on the high, rocky ridges above Yakima Park.

We found a variety of additional unusual forests which we were unable to classify. Several of these (for example, plots 348 and 433) were essentially riparian forests exhibiting unusual combinations of tree and understory dominants. *Populus trichocarpa* is a conspicuous dominant of old river bars; perhaps further sampling would have clarified the

vegetational composition of this community type. At least one of our plots (356) was classified as a *Tsuga heterophylla/Oplopanax horridum* association, but another containing both *Populus trichocarpa* and *Abies grandis* (plot 433 along the White River) was too unusual to be classified into any of the major associations or community types.

An all-aged *Pseudotsuga menziesii* forest on cobbly-skeletal soil occurs just outside the East Park boundary (Plot 292). We feel it is related to the *Pseudotsuga menziesii/Holodiscus discolor* Association (Dyrness et al. 1974), but have no further plots in the Mount Rainier area for comparison or grouping.

Several mature forest stands contained extremely sparse, vascular plant understories but conspicuous moss cover on the forest floor. Perhaps mossy forest community types or associations exist in the Park, especially on certain riparian sites or on cobbly or skeletal valley bottom soils. Our plots 34 and 205 are examples of mature mossy forests. These should not be confused, however, with shaded stages of immature forests on a variety of other habitat types in which mosses are also the most conspicuous understory layer.

Finally, we have a small residue of plots unclassified because they represent very young, early seral forests giving little hint to which, if any, of the associations or community types they are related. Several of these plots occurred on the 1947 Kautz mudflow, and another was a 48-year-old stand in the Golden Lakes area (just across a fireline from an older forest of the *Erythronium montanum* phase of *Abies amabilis/Rubus lasiococcus* association).

Chapter 6
Environmental and Floristic Relationships

Many of the floristic and environmental relationships between the plant communities have already been outlined in the introduction to the classification and discussions of the individual types. This section addresses more systematically both environmental and floristic patterns. The topographic-elevational relationships, as they vary around Mount Rainier, will be considered first. Then the details and adequacy of the classifications will be examined from the perspectives of similarity, discriminant, and principal component analyses.

Topographic-Elevational Patterns

The forest patterns at Mount Rainier are believed to be largely governed by moisture and temperature gradients (see Fig. 11). Moisture variations appear important at low elevations, and complex temperature and snowpack gradients are associated with higher elevations. Because of the substantial climatic and topographic variability in different sectors around the Mount Rainier cone, we constructed a generalized topographic-elevational pattern for each of the major drainage systems (Figs. 34 to 37).

Each of these diagrams (Figs. 34 to 37) presents generalized, simplified forest patterns reduced from far more complex mosaics actually occurring in the landscape. At this scale of generalization, we have overlooked microrelief features of dissected, geomorphically active, local landforms which produce intricate variations of vegetation distribution, including gradations from one forest type to another and interfingering of distinct types on uneven slopes and drainages. Slope effects can be envisioned as diagonal boundaries between habitat types as suggested in the caption of Figure 11. We have also generalized

through the complex age patterns of forest distributions. The contribution of the complex soils and their nutrient characteristics to the forest composition and structure is unknown. In addition, we can only speculate about the influence of other phenomena, such as dewpoint condensation and cloud cover, on the distribution of tree species from one drainage to the next. We can suggest from our principal component analysis that the topographic-environmental patterns of Figure 34 account for only about 30 to 40 percent of the variation of species distributions on the slopes of Mount Rainier; the remainder must be attributable to microsite, disturbance, and historical factors.

The Ohanapecosh River drainage (Fig. 34) is situated within a comparatively dry and warm sector of the Park (see Fig. 2). At lower elevations here, forests of TSHE/ACTR and TSHE/GASH are common on slopes and benches; they do not occur in appreciable amounts in the other drainages. The complex patterns at higher elevations reflect the

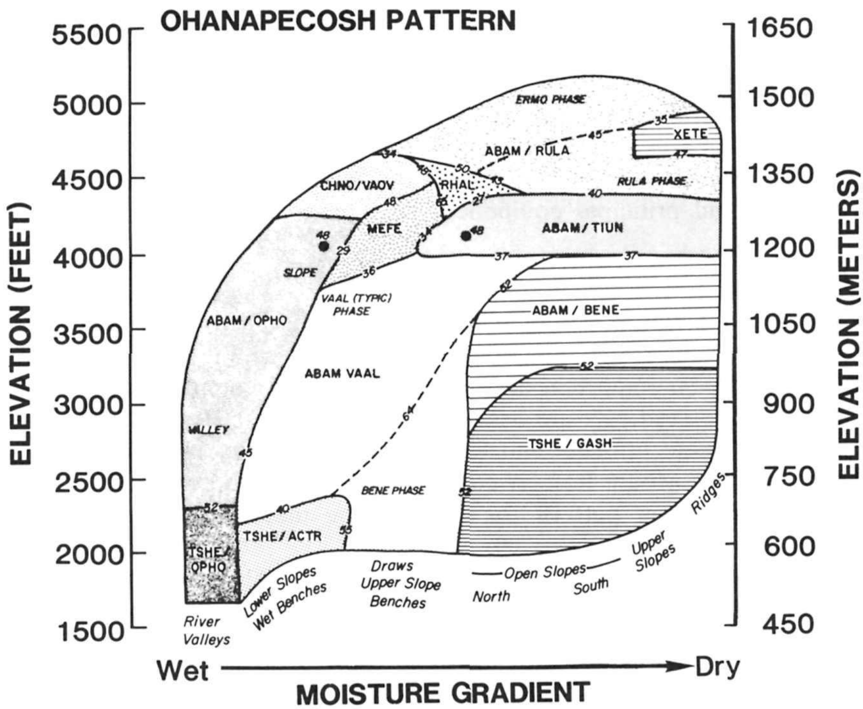

Figure 34. Generalized distribution of forest habitat types in the Ohanapecosh drainage. The horizontal axis depicts a generalized topographic moisture gradient from wet river valleys (left) to dry ridgetops (right). The shape of the overall forested area is determined by topographic features within the Ohanapecosh watershed. Numbers between adjoining habitat types are mean similarities (as percents) suggesting the degree of floristic relationship.

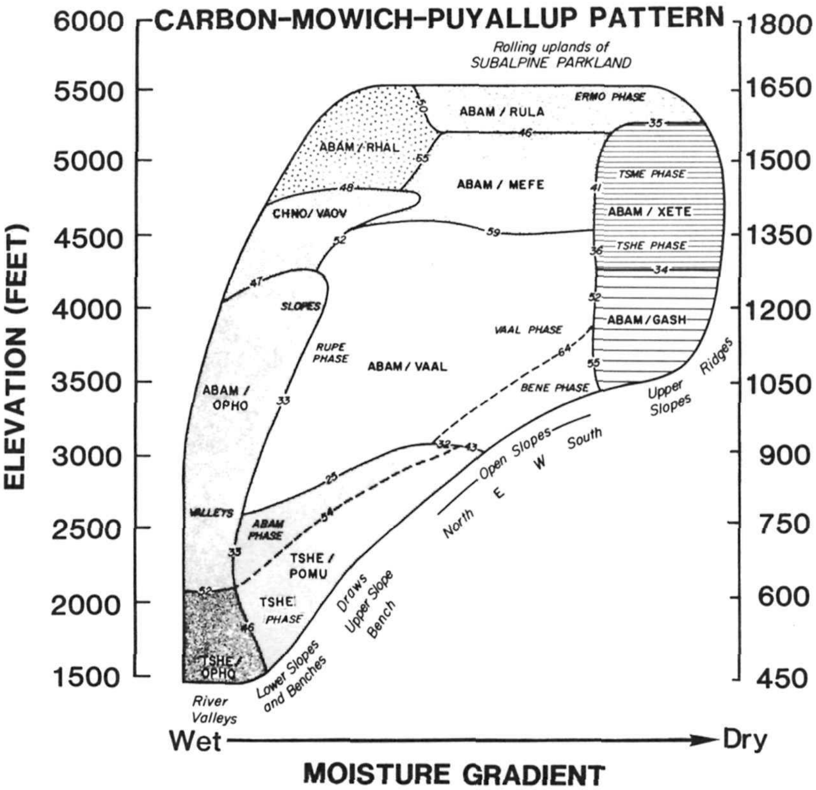

Figure 35. Generalized distribution of forest habitat types on northwestern drainages (Carbon, Mowich, Puyallup) of Mount Rainier. The horizontal axis depicts a generalized topographic moisture gradient from wet river valleys (left) to dry ridgetops (right). Numbers between adjoining types suggest the degree of floristic similarity based upon mean percent similarity.

forest-topographic relations of the Cowlitz Divide and upper Panther Creek and Laughingwater drainages.

At the other climatic extreme are the watersheds in the wetter, northwestern sector of the Park (Fig. 35). The forest patterns of the Carbon, Mowich, and Puyallup River drainages differ from the Ohanapecosh in major ways. At low elevations on lower slopes, draws, and benches, the TSHE/POMU Association is common; the *Abies amabilis* phase of this type is found at higher elevations or along north-facing lower slopes adjacent to the normal phase. Open or upper slopes between 1050 and 1200 m (3,500 to 4,000 ft) elevation are often forested with examples of the ABAM/GASH type; comparable landforms in the Ohanapecosh drainage are within the ABAM/BENE or ABAM/TIUN types. In the *Tsuga mertensiana* Zone, ABAM/RHAL, ABAM/MEFE, and ABAM/XETE types seem to occur more widely; these types are

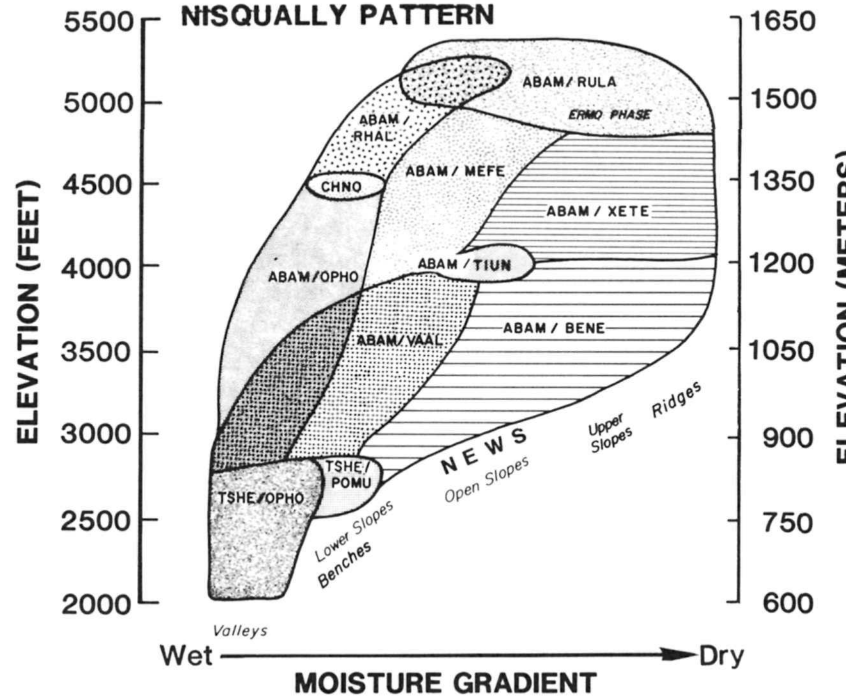

Figure 36. Generalized distribution of the Nisqually drainage of Mount Rainier National Park. The horizontal axis depicts a generalized topographic moisture gradient from wet river valleys (left) to dry ridgetops (right). The shape of the overall forested area is determined by topographic features within the Nisqually watershed. Numbers between adjoining habitat types are mean similarities (as percents) suggesting the degree of floristic relationship.

restricted in the Ohanapecosh where ABAM/TIUN and ABAM/RULA types sometimes occupy comparable elevation-topographic positions. The *Rubus pedatus* phase of the ABAM/VAAL Association is suggested as a high elevation, wetter, cooler environmental variation of this type, and is essentially absent in other sectors of the Park.

The Nisqually forest patterns are intermediate between the Ohanapecosh and Carbon sectors (Fig. 36). At 900 to 1050 m (3,000 to 3,500 ft), ABAM/BENE forests are common on slopes and ridges; these adjoin ABAM/XETE forests of upper slopes or ridges at higher elevation. Stands of ABAM/VAAL and ABAM/TIUN occupy the modal microenvironments of mesic soils and moderate thermal regimes. Stands of ABAM/OPHO and ABAM/VAAL occupy valley floors, toe-slopes, or lower elevation benches. Considerable topographic overlap occurs in the distribution of ABAM/RULA and ABAM/RHAL Associations at higher elevations. Clearly, soil drainage, snowpack, and other

environmental features of microsites are also important in the distribution of forest habitats (Long 1976).

The White River drainage is the most continental of the forest climates in Mount Rainier (Fig. 37). Forests with high proportions of *Picea engelmannii* may be found at the upper elevations of glacial valleys, and *Pinus contorta* occurs in periglacial environments of moraines and rockfields around 1350 m (4,500 ft) elevation. Forests of *Abies lasiocarpa* are conspicuous at high elevations on warm, dry margins of a subalpine forest climate. At midelevations, 900 to 1200 m (3,000 to 4,000 ft), the sequence from wet to dry environments along a topographic moisture gradient is ABAM/OPHO, ABAM/VAAL, and ABAM/BENE. This is generally comparable to forest distribution in the Ohanapecosh and Nisqually River drainages. The wet, warm TSHE/

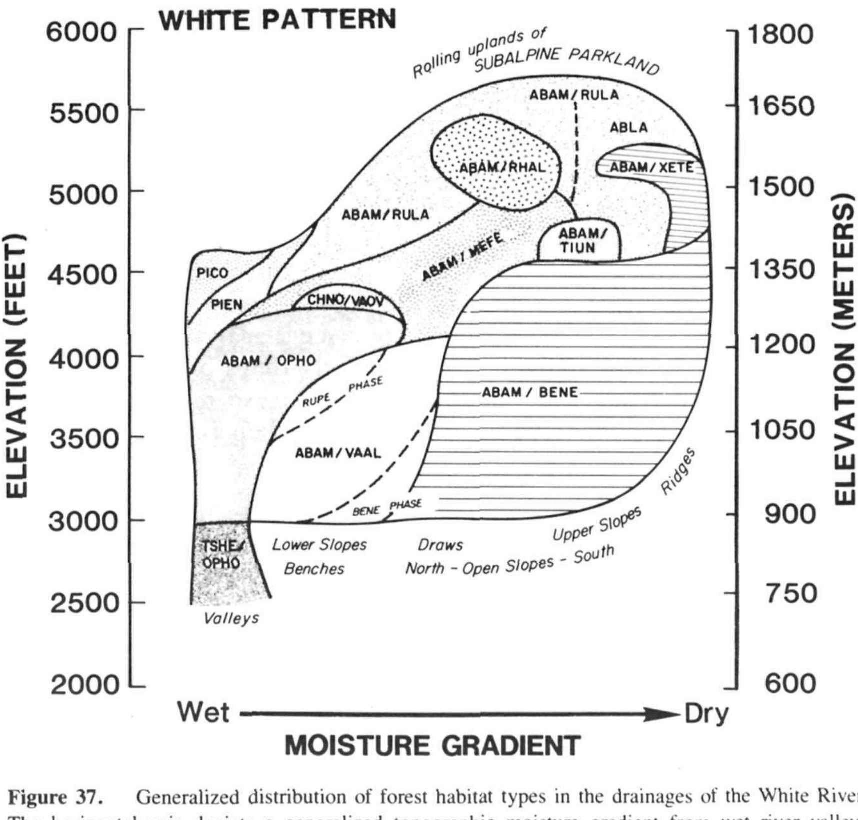

Figure 37. Generalized distribution of forest habitat types in the drainages of the White River. The horizontal axis depicts a generalized topographic moisture gradient from wet river valleys (left) to dry ridgetops (right). The shape of the overall forested area is determined by topographic features within the White watershed. Numbers between adjoining habitat types are mean similarities (as percents) suggesting the degree of floristic relationship.

OPHO forest is restricted to lower valleys of the White River in vicinity of the Park boundary.

Classification Insights from Similarity, Discriminant, and Principal Component Analyses

Classifying the forests at Mount Rainier is not an easy task. Within a local area the types are sometimes sharply defined with abrupt ecotones. As abstractions, the types we have recognized represent distinctive compositional (including relative species importance) nodes. Both environmental and floristic gradients are typically continuous, however, and the involved forest flora is composed mainly of species with broad ecological amplitudes rather than species of high fidelity to limited environmental conditions. The complexity of the mountain environment at Mount Rainier, with the presence of many highly limited and individualistic site conditions within a limited area, further complicates the job of classification. Under these circumstances, gradual transitions from one type to another are encountered in field situations, and plots intermediate between types do occur. We say this not by way of an apology for the classification but, rather, so that the user is aware of its limitations.

We have used various statistical and analytical procedures in constructing this classification system and can provide some insight into its general validity. These include: (1) similarity analyses, which can show the degree to which types are related; (2) discriminant analyses, which can be used to reexamine classification of old plots as well as assign new plots to types; and (3) principal component analyses, which can be used to examine how individual species and groups of species respond to complex gradients and, in turn, see how these relate to the typal groupings and hypothesized environmental gradients.

Similarity Analysis

We used similarity analysis to develop this classification (explained in step 4 of the "Data Analysis" section in Chapter 4); abstracted results of one analysis at the level of forest type comparisons (contrasted with analysis of individual plots) are shown in Table 11. In constructing this table we recognized that similarity values are conditioned by whatever algorithm is used to compare forest types (for example, Kelsey et al. 1977). These values also depend on the choice of plant species whose average cover or density was used to compute the percentage of similarity. Our similarity values ranged from 12 to 65 percent. Forest types are extremely similar, we feel, for similarities greater than 55 percent; they are highly similar between 47 and 55 percent, and similar

in the range of 40–56 percent. These similarity classes are based on forest type comparisons involving the first 400 plots.

The results of Table 11 generally support the discussion of related forest types included in earlier presentations. This table highlights the floristically similar forests whose significance, we believe, is that they represent intergrading environments along complex moisture, temperature, nutrient, or successional gradients (Dyrness et al. 1974, Zobel et al. 1976). The following comparisons are noteworthy:

- At lower elevations, the *Tsuga heterophylla*/*Gaultheria shallon* Association has the greatest overall similarity to other forest types, especially *Tsuga heterophylla*/*Achlys triphylla*, *Pseudotsuga menziesii*/*Viola sempervirens*, *Abies amabilis*/*Gaultheria shallon*, *Abies amabilis*/*Berberis nervosa*, and *Abies amabilis*/*Vaccinium alaskaense* Associations. As shown in the topographic-elevational patterns (Figs. 34 to 37), several of the associations highly similar to *Tsuga heterophylla*/*Gaultheria shallon* are ecotonal or found on topographically identical positions of the landscape in different sectors of the Park.
- At intermediate elevations, the *Berberis nervosa* phase of *Abies amabilis*/*Vaccinium alaskaense* Association bears the greatest overall similarity to most of the other community types or associations and is extremely similar to *Abies amabilis*/*Berberis nervosa* Association. This underscores our belief that *Abies amabilis*/*Vaccinium alaskaense* is the vegetation of modal environments.
- At high elevations, several associations are very difficult to separate floristically. For those species chosen to make similarity comparisons, the *Abies amabilis*/*Menziesia ferruginea* Association is extremely similar to the *Rubus pedatus* phase of *Abies amabilis*/*Vaccinium alaskaense* and to the *Abies amabilis*/*Rhododendron albiflorum* Associations. These associations, as well as the *Erythronium* phase of *Abies amabilis*/*Rubus lasiococcus* and *Chamaecyparis nootkatensis*/*Vaccinium ovalifolium* Associations, doubtless represent subtly intergrading environments of high snowpack and short growing seasons.
- Seral community types may show little similarity to the more mature associations. The *Alnus rubra*/*Rubus spectabilis* and *Abies lasiocarpa*/*Valeriana sitchensis* community types are especially distinctive. These young forests can be nearly monocultures of an early seral tree dominant as well as having pronounced dominance by understory plants (such as *Pteridium aquilinum*) that decline as the sere develops. The three *Pseudotsuga menziesii* community types are floristically similar to each other, but only *Pseudotsuga menziesii*/*Xerophyllum tenax* has similarity with some of the other associations.

Table 11. Classes of percent similarity between all forest types in Mount Rainier National Park.[1]

Forest type[2]			Forest type[2] 1	2 a	2 b	3	4	5 a	5 b	6 a	6 b	7 a	7 b	7 c	7 d	8	9	10	11	12	13	14 a	14 b	14 c	15 a	15 b	16	17	18	19 a	19 b
1	TSHE/ACTR[3]		*																												
2a	TSHE/POMU,	TSHE phase	2	*																											
2b	TSHE/POMU,	ABAM phase	2	5	*																										
3	TSHE/OPHO		2	4	3	*																									
4	ALRU/RUSP		2	1	1	3	*																								
5a	ABAM/OPHO,	valley phase	2	3	3	5	3	*																							
5b	ABAM/OPHO,	slope phase	2	3	2	5	4	5	*																						
6a	ABAM/TIUN,	climax phase	3	2	1	3	3	4	5	*																					
6b	ABAM/TIUN,	seral phase	4	1	1	2	2	3	4	5	*																				
7a	ABAM/VAAL,	VAAL phase	2	1	1	1		3	2	2	2	*																			
7b	ABAM/VAAL,	BENE phase	3	3	3	1		2	1	1	2	4	*																		
7c	ABAM/VAAL,	RUPE phase		1	1	1		3	2	2	1	5	3	*																	
7d	ABAM/VAAL,	CHNO phase	1		1			2	1	1	1	5	3	5	*																
8	TSHE/GASH		3	2	2	1		1		1	1	1	3		1	*															
9	PSME/CEVE		2	1		1	1			1	2	1	1	1		1	*														
10	PSME/XETE		2	1	1	1	1	1		1	2	2	2	1	2	3	3	*													
11	PSME/VISE		5	2	3	2	2	3	2	3	3	2	5	1	1	3	3	3	*												
12	ABAM/GASH		1	2	2			2			1	3	4	2	3	5	1	4	2	*											
13	ABAM/BENE		5	3	3	2	2	3	2	3	3	3	5	1	1	4	2	3	5	2	*										
14a	ABAM/XETE,	TSHE phase	1	1	1			1		1		2	2	1	2	2	1	5	2	4	2	*									
14b	ABAM/XETE,	TSME phase							1	1	1	1		1	2	1	1	5	1	2	1	5	*								
14c	ABAM/XETE,	seral phase	1					1	1	1	2	2	2	2	2		1	5	2	3	1	5	5	*							
15a	ABAM/RULA,	RULA phase	1	1	1	1	1	2	2	3	3	2	1	2	2	1	1	3	2	1	2	2	4	3	*						
15b	ABAM/RULA,	ERMO phase						1	1	2	2	1		1	2		1	2	1	1		1	4	3	5	*					
16	ABLA2/VASI							1	1	3	3	1	1	1	1		1	3	1	1	1	2	3	3	4	3	*				
17	ABAM/RHAL							2	1	2	1	3	1	3	3		1	2	1	1		1	3	3	3	4	2	*			
18	CHNO/VAOV		1	1	1	1	1	3	4	5	3	3	1	4	3		1	1	1	1	1	1	2	2	3	3	2	4	*		
19a	ABAM/MEFE,	climax phase						3	2	2	2	4	2	5	4		1	2	1	2	1	2	3	4	4	3	3	5	5	*	
19b	ABAM/MEFE,	seral phase						2	1	2	2	3	2	3	3	1	1	3	2	2	1	2	4	4	4	3	3	5	3	5	*

[1]Percent similarity (Gauch 1982) computed using relative average cover of all herb and shrub species within each forest type. Seven classes are defined as follows: blank < 10%, 10% ≤ 1 < 20%, 20% ≤ 2 < 30%, 30% ≤ 3 < 40%, 40% ≤ 4 < 50%, 50% ≤ 5 < 100%, * 100%.

[2]Forest type numbers and acronyms correspond with those in Table 1.

[3]ABAM = *Abies amabilis*, ABLA2 = *Abies lasiocarpa*, ACTR = *Achlys triphylla*, ALRU = *Alnus rubra*, BENE = *Berberis nervosa*, CEVE = *Ceanothus velutinus*, CHNO = *Chamaecyparis nootkatensis*, ERMO = *Erythronium montanum*, GASH = *Gaultheria shallon*, MEFE = *Menziesia ferruginea*, OPHO = *Oplopanax horridum*, POMU = *Polystichum munitum*, PSME = *Pseudotsuga menziesii*, RULA = *Rubus lasiococcus*, RUPE = *Rubus pedatus*, RUSP = *Rubus spectabilis*, TIUN = *Tiarella unifoliata*, TSHE = *Tsuga heterophylla*, TSME = *Tsuga mertensiana*, VAAL = *Vaccinium alaskaense*, VAOV = *Vaccinium ovalifollum*, VASI = *Valeriana sitchensis*, VISE = *Viola sempervirens*, XETE = *Xerophyllum tenax*.

Discriminant Analysis

The discriminant classification, based on 39 discriminant variables, is summarized in Table 12. The 19 groups in the left-most column are the defined habitat and community types. The ecological and floristic characteristics used in defining these 19 forest types were not necessarily the same variables used in computing the discriminant functions. Variables employed in discriminant analysis were chosen from important species considering forest vegetation over the entire forest region, but those used to resolve the 19 forest groups were selected from important species within each of four broad environmental groups (moist, modal, dry, and cold) at Mount Rainier. Therefore, the groups defined by discriminant analysis are less sharply resolved in cases where an important classificatory variable within a subgroup is not included in the analysis. On the other hand, zonal differences between vegetation groups may be more clearly separated in the discriminant classification.

An interesting sidelight of the discriminant analysis illustrates one problem of defining vegetation groups. The set of species chosen as variables had low coverage or density values in several of the *Abies amabilis/Berberis nervosa* plots used in the analysis. Consequently, plots from distinctly dissimilar vegetation types were often incorrectly classified as an *Abies amabilis/Berberis nervosa* Association if they had low total shrub and herb coverage.

The circular analytic pathway is another consideration for interpreting the discriminant matrix (Table 12). In effect, the computer is told what the initial groups are (left column of Table 12); it then computes optimally discriminating functions, and in a second pass over the plot data reassigns each plot to a group. No matter how poorly or skillfully the initial group classification was made, this method assures that a certain proportion of the forest plots are "correctly" assigned to the original groups. It is conceivable that by careful choice of discriminating variables, all or most of the plots could be correctly classified no matter how valid the *a priori* classification of groups.

Each of the 19 numbered columns in Table 12 represents a forest group used to calculate discriminant functions by the procedure described by Nie et al. (1975). Plots "correctly" classified are tallied in the main diagonal; those assigned to other than their initial group are tallied in the appropriate off-diagonal column. The proportion of correctly reassigned plots is shown in the right-hand column of Table 12.

One of the benefits of using discriminant analysis is its computational ability to screen the classified plots for possible misclassification. Misclassified plots will appear off the diagonal in such an analysis. However, plots off the diagonal in our analysis are not necessarily misclassified because we used less information to discriminate the

groupings than was used to resolve the initial forest groups. To decide whether or not any off-diagonal plot has been misclassified requires examination of the entire plot data (including environmental and successional information) and exercise of ecological judgment. Of all our plots, 25 percent were off diagonal. About 10 percent of those were either misclassified in the initial forest groupings or were intergrades between two groups, thus having about equal probability of assignment to either group.

Table 12 suggests floristic affinities between the forest groups based on the 39 variables used in the discrimination. Groups 5a and 5b (*Abies amabilis/Oplopanax horridum*, valley and slope phases, respectively) have floristic similarity, for example, because off-diagonal plots occur within both groups. We feel, however, that this expression of floristic relationship is less persuasive than actual similarity measures between the different forest types shown, for example, in Table 11.

For a discussion of the logic, assumptions, and algorithms used in discriminant analysis, see either Nie et al. (1975) or Cooley and Lohnes (1971).

Principal Component Analysis

Principal component analysis (PCA) was applied to plots within each of the four major environmental groupings (step 3 of the "Data Analysis" section, Chapter 4). As a technique of indirect ordination, interpretation of PCA focuses on the meaning of whatever environmental gradients are represented by the component axes. Since most species have curvilinear distributions along complex environmental gradients, only those species whose distributions can be approximated linearly will show high "factor loadings." Tables 13 to 16 show these loadings within each of the four environmental groupings.

As a classification procedure, however, we used PCA to identify sets of species responding in approximately the same quasi-linear manner to the environmental gradients reflected in the component axes. These sets are suggested as ecological groupings under the assumption that each component axis does, in fact, reflect some kind of complex environmental gradient along which various species may be distributed according to their particular tolerances and competitive abilities. If, for example, a species is indifferent to the environmental factors reflected in a particular PCA component, or if it has a marked curvilinear response, then its factor loading will be small. Should a species respond positively and more or less linearly to environmental factors reflected by the component axis, it will have a relatively high factor loading. Conversely, a species having the opposite and more or less linear response will have a high negative factor loading. Species with nearly similar

Table 12. Summary of discriminant analysis on forest types in Mount Rainier National Park[1]

	Forest type[2]	Forest type[2]																			Number of plots	Percent plots correctly classified
		1	2	3	5a	5b	6	7	8	9	10	11	12	13	14	15	16	17	18	19		
1.	TSHE/ACTR[3]	4										1									5	80
2.	TSHE/POMU		10									5		1							16	63
3.	TSHE/OPHO			16	2	1						1		1	1						22	73
5a.	ABAM/OPHO			2	9	3					1	2		2	1				1		21	42
5b.	ABAM/OPHO				1	7									2				1		11	64
6.	ABAM/TIUN			1										1	16	1					19	84
7.	ABAM/VAAL			1	1							2		43		1			3		51	84
8.	TSHE/GASH						7				1	2									10	70
9.	PSME/CEVE							2				1									3	67
10.	PSME/XETE						1		3				1								5	60
11.	PSME/VISE	2							1	8			1								12	75
12.	ABAM/GASH						2		1		10	1		1							15	67
13.	ABAM/BENE									2		27									29	93
14.	ABAM/XETE								1			3	14			4					22	64
15.	ABAM/RULA												1		1	24	1	2			29	83
16.	ABLA[2]/VASI															1	10				11	91
17.	ABAM/RHAL													2	1	3				11	17	65
18.	CHNO/VAOV										1			1	1				11		14	79
19.	ABAM/MEFE															3		15	1		19	78

[1]Plots classified "correctly" according to the analysis (total 75 percent) are on the main diagonal; "incorrectly" classified plots are off the diagonal.
[2]Names and numbers of the types correspond with those in Table 1.
[3]TSHE/ACTR = *Tsuga heterophylla/Achlys triphylla*, TSHE/POMU = *Tsuga heterophylla/Polystchum munitum*, TSHE/OPHO = *Tsuga heterophylla/Oplopanax horridum*, ABAM/OPHO = *Abies amabilis/Oplopanax horridum*, ABAM/TIUN = *Abies amabilis/Tiarella unifoliata*, ABAM/VAAL = *Abies amabilis/Vaccinium alaskaense*, TSHE/GASH = *Tsuga heterophylla/Gaultheria shallon*, PSME/CEVE = *Pseudotsuga menziesii/Ceanothus velutinus*, PSME/XETE = *Pseudotsuga menziesii/Xerophyllum tenax*, PSME/VISE = *Pseudotsuga menziesii/Viola sempervirens*, ABAM/GASH = *Abies amabilis/Gaultheria shallon*, ABAM/BENE = *Abies amabilis/Berberis nervosa*, ABAM/XETE = *Abies amabilis/Xerophyllum tenax*, ABAM/RULA = *Abies amabilis/Rubus lasiococcus*, ABLA[2]VASI = *Abies lasiocarpa/Valeriana sitchensis*, ABAM/RHAL = *Abies amabilis/Rhododendron albiflorum*, CHNO/VAOV = *Chamaecyparis nootkatensis/Vaccinium ovalifolium*, ABAM/MEFE = *Abies amabilis/Menziesia ferruginea*.

ecological tolerances and similar distributions along environmental gradients should have about the same factor loadings.

In discussing the results of PCA (Tables 13 to 16), we identify species which may be ecologically similar and see how these might coincide with species assemblages characteristic of the forest types. Whenever possible, principal components are also tentatively interpreted as environmental gradients.

Cold or High-Elevation Forests—The four components of Table 13 collectively account for 34 percent of the variation in the R matrix. The first component accounts for 12 percent of this variation. This component reflects some environmental complex along which shrubs *Vaccinium ovalifolium* and *Menziesia ferruginea* respond positively, whereas mesic herbs, often of subalpine parkland affinity, respond negatively, as does *Abies lasiocarpa*. The second component accounts for 9 percent of the variation in the R matrix and seems to reveal a "wetness" gradient along which herbs such as *Tiarella unifoliata, Trautvettaria, Gymnocarpium*, et al. have positive response. Responding in an opposite way to this component is *Vaccinium membranaceum*. The third component, with 7 percent of the variation in the R matrix, might be interpreted as an axis of temperature or snowpack duration. *Rhododendron albiflorum, Vaccinium membranaceum*, and *Erythronium montanum* respond positively, whereas *Xerophyllum tenax* and *Chimaphila umbellata* exhibit opposite responses. The fourth component, with 6 percent of the R matrix variation, is some kind of gradient affecting shrub cover, for *Vaccinium alaskaense* and *V. ovalifolium* and *Menziesia ferruginea* all have positive factor loadings.

The species in Table 13 can be grouped by their similar patterns in each of the four PCA components:

1. *Abies lasiocarpa, Rubus lasiococcus, Valeriana sitchensis, Luzula glabrata, Arnica latifolia, Clintonia uniflora*, and *Vaccinium deliciosum**;
2. *Menziesia ferruginea* and *Vaccinium ovalifolium*;
3. Mature *Chamaecyparis nootkatensis, Tiarella unifoliata, Trautvettaria grandis, Viola glabella, Gymnocarpium dryopteris, Osmorhiza* spp., *Streptopus roseus*, and *Rubus pedatus*;
4. Mature *Tsuga heterophylla, Xerophyllum tenax*, and *Chimaphila umbellata*;
5. Young *Tsuga mertensiana, Rhododendron albiflorum*, and *Erythronium montanum*;
6. *Vaccinium alaskaense*; and
7. *Pyrola secunda, Rubus lasiococcus**, and *Clintonia uniflora**.

Table 13. Factor loadings of tree and understory variables on the first four components from principal component analysis, 125 cold or high-elevation plots, Mount Rainier National Park[1]

Variable[2]	Component[3] 1	2	3	4	[4]R^2
Abies amabilis, mature				−0.55	49
Abies amabilis, young	0.42		0.35		38
Abies lasiocarpa, mature	−.78				82
Abies lasiocarpa, young	−.61				67
Chamaecyparis nootkatensis, mature		.40			38
Tsuga heterophylla, mature			−.66		46
Tsuga mertensiana, young			.47		46
Arnica latifolia	−.46				40
Chimaphila umbellata			−.41		28
Clintonia uniflora	−.38				55
Erythronium montanum			.42		46
Gymnocarpium dryopteris		.59			52
Luzula glabrata	−.48				70
Osmorhiza spp.		.59			54
Pyrola secunda				−.50	38
Rubus lasiococcus	−.71				68
Rubus pedatus		.40			49
Streptopus roseus		.48			43
Tiarella unifoliata		.76			61
Trautvetteria grandis		.66			60
Valeriana sitchensis	−.68				58
Viola glabella		.62			59
Xerophyllum tenax			−.47		36
Menziesia ferruginea	.43			.40	51
Rhododendron albiflorum			.44		29
Vaccinium alaskaense				.47	43
Vaccinium membranaceum		−.38	.31		31
Vaccinium ovalifolium	.44			.44	51

[1]Principal component analysis was performed on raw data from 125 plots.
[2]Noncorrelated variables: *Chamaecyparis nootkatensis* (young), *Tsuga heterophylla* (young), *T. mertensiana* (mature), *Alnus sitchensis*, *Vaccinium deliciosum*, and *Viola sempervirens*.
[3]Only the highest loadings have been given for each component.
[4]Values are the squares of the multiple correlation between each variable and others in the set.

Species with asterisks (*) were added to the group only when the masking effects of very strong correlations associated with dominance of *Abies lasiocarpa* were removed by deleting *A. lasiocarpa*-dominated plots from PCA. The seven groupings above were analogous to the assemblages of species that were identified with forest types recognized by the following similarity analysis:

Forest Type	Principal component and factor loadings (+ or −)	
	With *Abies lasiocarpa*	Without *Abies lasiocarpa*
Abies lasiocarpa/Valeriana sitchensis	1 −	
Abies amabilis/Rubus lasiococcus, *Rubus lasiococcus* phase		2 +
Abies amabilis/Rubus lasiococcus, *Erythronium montanum* phase	3 +	3 +
Abies amabilis/Rhododendron albiflorum	3 +	3 +
Abies amabilis/Menziesia ferruginea	4 +	2 −
Chamaecyparis nootkatensis/Vaccinium alaskaense	3 −	3 −

Thus, many species of the *Abies lasiocarpa/Valeriana sitchensis* Community Type showed negative responses to the first PCA component. Certain species of the *Rubus lasiococcus* phase of the *Abies amabilis/Rubus lasiococcus* Association had positive factor loadings to the second PCA component of the reduced analysis without *Abies lasiocarpa* stands. The third PCA component (in both analyses) appears to be coincident to both the *Abies amabilis/Rhododendron albiflorum* Association and the *Erythronium montanum* phase of the *Abies amabilis/Rubus lasiococcus* Association.

In general, the above tabulation suggests that the complex environmental space of the R matrix, defined in part by each of the major PCA components, roughly resembles the environmental stratification of the *Tsuga mertensiana* Zone defined by the associations.

Forests of Valleys, Wet Slopes, and Benches—The factor analysis of plots of streamsides, wet slopes, and benches is presented in Table 14. Most plots were characterized by an abundance of *Oplopanax horridum* and were very rich in herbaceous assemblages. Trees restricted to these environments were *Abies grandis* and *Picea sitchensis* at low elevations.

The first axis generally appears to be an elevational gradient. Negative factor loadings are seen for such low elevation species as *Thuja plicata*, *Polystichum munitum*, and *Berberis nervosa*. Higher elevation plants have positive factor loadings, and include young *Abies amabilis*,

Vaccinium ovalifolium, *Vaccinium alaskaense*, and such herbs as *Clintonia uniflora*, *Rubus lasiococcus*, and *Streptopus roseus*.

Eight percent of the R matrix variation is accounted by the second axis, which clearly relates to streamside *Alnus rubra* environments (the *Alnus rubra/Rubus spectabilis* Community Type). A very large share of variance of *Alnus rubra* is centered on this axis. Understory species of high factor loadings are *Rubus spectabilis*, *Achlys triphylla*, and *Pteridium aquilinum*.

The third axis is difficult to interpret, but seems to highlight low-elevation seral plots associated with *Pseudotsuga menziesii*. Species relating to this unkown environmental gradient include *Abies grandis*, *Cornus canadensis*, *Viola sempervirens*, and *Vaccinium parvifolium*.

The following ecological groupings in wetter valley and lower-slope environments are revealed in Table 14:

1. Young *Abies amabilis*, *Clintonia uniflora*, *Streptopus roseus*, *Rubus lasiococcus*, *Smilacina stellata*, *Vaccinium alaskaense*, *Vaccinium ovalifolium*, and *Vaccinium membranaceum*;
2. *Tsuga heterophylla*, mature *Thuja plicata*, *Polystichum munitum*, and *Berberis nervosa*;
3. *Alnus rubra*, *Rubus spectabilis*, *Pteridium aquilinum*, *Montia sibirica*, *Achlys triphylla*, and *Circaea alpina*; and
4. *Pseudotsuga menziesii*, *Abies grandis*, *Viola sempervirens*, *Cornus canadensis*, and *Vaccinium parvifolium*.

Important noncorrelated species of these wet environments include such widespread dominants as *Gymnocarpium*, *Oplopanax*, and *Tiarella* spp. Locally dominant, noncorrelated species are *Blechnum spicant*, *Corydalis scouleri*, and *Oxalis oregana*. The more widespread and constant species reveal no apparent (linear) trend with elevation, and are not specific to seral environments. The locally dominant species occur too sporadically to indicate trends or environmental preferences.

Mesic Forests of the Abies amabilis Zone—Results of PCA from plots occurring mostly on *Abies amabilis/Vaccinium alaskaense* and *Abies amabilis/Tiarella unifoliata* habitats are given in Table 15. The three components collectively account for 31 percent of the R matrix variation. The first component differentiates mesic herbs (positive factor loadings) from the shrub *Vaccinium alaskaense*. In other words, this component represents an environmental axis that essentially separates the *Abies amabilis/Tiarella unifoliata* and *Abies amabilis/Vaccinium alaskaense* Associations, and might be thought of as an "herb cover gradient." The following herbs had high factor loadings: *Tiarella unifoliata*, *Streptopus roseus*, *Achlys triphylla*, *Valeriana sitchensis*, *Gymnocarpium dryopteris*, *Smilacina stellata*, and *Viola glabella*.

Table 14. Factor loadings of tree and understory variables on the first three components from factor analysis, on 78 streamside or lower slope plots, Mount Rainier National Park[1]

Variable[2]	Factor 1	Factor 2	Factor 3	[3]h^2
				Percent
Abies amabilis, young	0.75			59
Abies grandis			0.61	38
Alnus rubra		0.77		64
Pseudotsuga menziesii, young			.68	48
Pseudotsuga menziesii, mature			.47	38
Thuja plicata, mature	−.31			26
Tsuga heterophylla, mature	−.32	−.57		46
Achlys triphylla		.52		36
Berberis nervosa	−.26			26
Circaea alpina		.41		30
Clintonia uniflora	.76			58
Cornus canadensis			.57	41
Montia sibirica		.53		33
Polystichum munitum	−.40			31
Pteridium aquilinum		.50		40
Rubus lasiococcus	.60			53
Smilacina stellata	.45			21
Streptopus roseus	.68			49
Viola sempervirens			.49	31
Rubus lasiococcus		.79		65
Vaccinium alaskaense	.59			37
Vaccinium membranaceum	.45			26
Vaccinium ovalifolium	.69			48
Vaccinium parvifolium			.47	27
Percent variation accounted for	9.6	8.0	6.3	

[1]Factor analysis was performed on raw data from 78 plots.
[2]Noncorrelated variables: *Picea* spp., *Acer circinatum*, *Blechnum spicant*, *Corydalis scouleri*, *Gymnocarpium dryopteris*, *Oplopanax horridum*, *Oxalis oregana*, *Tiarella unifoliata*, and *Tiarella trifoliata*.
[3]The proportion of variance for each variable accounted for by a rank 4 model.

The second component is roughly an elevational axis through the *Abies amabilis/Vaccinium alaskaense* environmental complex. Species of warmer sites include *Linnaea borealis* and *Cornus canadensis*; those of cooler, higher elevations are *Vaccinium ovalifolium*, *Rubus pedatus*,

Table 15. Factor loadings of tree and understory variables on the first three components from principal component analysis, 98 plots on mesic slopes and benches at intermediate elevation, Mount Rainier National Park[1]

Variable[2]	Component 1	Component 2	Component 3	[3]h^2
				Percent
Abies amabilis, young		0.53		29
Chamaecyparis nootkatensis			0.51	76
Tsuga mertensiana		.43		29
Achlys triphylla	0.70			66
Cornus canadensis		−.51		41
Gymnocarpium dryopteris	.54		−.56	74
Linnaea borealis		−.47		57
Rubus pedatus		.52		29
Smilacina stellata	.56		.41	66
Streptopus roseus	.75		−.32	78
Tiarella unifoliata	.82		−.32	87
Valeriana sitchensis	.62		−.44	71
Viola glabella	.56			34
Viola sempervirens			.43	62
Menziesia ferruginea		.32	.30	30
Vaccinium alaskaense	−.55	.34		43
Vaccinium ovalifolium		.57		49
Percent variation accounted for	12.8	9.9	7.9	

[1]Principal component analysis was performed on raw data from 98 plots.
[2]Noncorrelated variables: *Abies procera*, *Pseudotsuga menziesii*, mature, *Acer circinatum*, *Berberis nervosa*, *Clintonia uniflora*, *Oplopanax horridum*, *Rubus lasiococcus*, *Vaccinium membranaceum*, and *Xerophyllum tenax*.
[3]Proportion of variance for each variable accounted for by the first five principal components.

and *Menziesia ferruginea*. This environmental axis might pass through the *Berberis nervosa* phase of the *Abies amabilis*/*Vaccinium alaskaense* Association at lower elevations and the *Rubus pedatus* phase at higher elevations.

The third component is difficult tc interpret. It separates herbs into two categories. *Smilacina stellata* and *Viola sempervirens* (as well as *Chamaecyparis nootkatensis* and *Menziesia ferruginea*) have positive factor loadings, whereas *Gymnocarpium dryopteris*, *Valeriana sitchensis*, *Tiarella unifoliata*, and *Streptopus roseus* respond in the opposite

manner. This component is some obscure complex gradient through both *Abies amabilis/Tiarella unifoliata* and phases of the *Abies amabilis/Vaccinium alaskaense* environment.

Forests of Warm or Dry Sites—The PCA components of Table 16 segregate five vegetation groups:

1. Mesic herbs with positive factor loadings on the first component and negative loadings on the second: *Viola sempervirens, Achlys triphylla, Tiarella unifoliata*, and *Smilacina stellata*;
2. Other mesic herbs of positive factor loadings on the first component: *Cornus canadensis, Rubus lasiococcus, Rubus ursinus, Linnaea borealis*, and *Gaultheria ovatifolia*;
3. Species with positive loadings along the second axis: young *Pseudotsuga menziesii, Vaccinium membranaceum, Xerophyllum tenax*, and *Gaultheria ovatifolia*;
4. Low shrubs and a woody herb with negative factor loadings on the third axis: *Berberis nervosa, Chimaphila umbellata*, and *Arctostaphylos uva-ursi*; and
5. Trees and shrubs with positive factor loadings on the fourth component: *Abies amabilis, Tsuga heterophylla, Vaccinium alaskaense*, and *Vaccinium parvifolium*.

These species groupings also generally coincide with species optima in various community types:

Community type	Principal component and factor loading (+ or −)
Tsuga heterophylla/Achlys triphylla, Pseudotsuga menziesii/Xerophyllum tenax	1 +
Pseudotsuga menziesii/Xerophyllum tenax	2 +
Pseudotsuga menziesii/Ceanothus velutinus	3 +
Abies amabilis/Berberis nervosa	3 −
Abies amabilis/Vaccinium alaskaense, Berberis nervosa phase	4 +

The first component reflects an environmental gradient affecting herb richness, perhaps in soil nutrition. Our major herb-dominated, low elevation habitats generally encompass this component. The second PCA axis takes into account much of the variation of *Vaccinium membranaceum, Xerophyllum tenax*, and *Gaultheria ovatifolia*, whereas mesic herbs (*Achlys triphylla, Smilacina stellata, Tiarella unifoliata*, and *Viola sempervirens*) respond in opposite manner. This axis might be a complex elevational-topographic moisture gradient reflecting, perhaps, intensities of summer soil drought. The third component may reflect an environmental (possibly elevational) gradient of rather dry, slope environments involving both the *Pseudotsuga menziesii/*

Table 16. Factor loadings of tree and understory variables on the first four components from principal component analysis, 94 plots on warm or dry sites at low elevations, Mount Rainier National Park[1]

Variable[2]	Component[3] 1	2	3	4	[4]R^2
Abies amabilis, young	−0.34			0.43	42
Pseudotsuga menziesii, young		0.49			48
Tsuga heterophylla, young				.56	
Achlys triphylla	.51	−.58			74
Arctostaphylos uva-ursi			0.41		50
Berberis nervosa			−.69		56
Chimaphila umbellata			−.68		63
Cornus canadensis	.60				67
Gaultheria ovatifolia	.40	.51			71
Linnaea borealis	.59		−.42		66
Rubus lasiococcus	.65				75
Rubus ursinus	.52				54
Smilacina stellata	.34	−.36			48
Tiarella unifoliata	.41	−.46			51
Viola sempervirens	.64	.50			76
Xerophyllum tenax		.47			57
Vaccinium alaskaense				.79	59
Vaccinium membranaceum		.59			56
Vaccinium parvifolium				.50	60
Percent variation accounted for	11.4	9.0	7.6	7.0	

[1]Principal component analysis was performed on raw data from 94 plots.
[2]Noncorrelated variables: *Abies procera*, *Thuja plicata*, *Acer circinatum*, *Clintonia uniflora*, *Fragaria* spp., *Gaultheria shallon*, *Hieracium albiflorum*, *Pachistima myrsinites*, *Pteridium aquilinum*, *Rosa gymnocarpa*, *Symphoricarpos mollis*, and *Trientalis latifolia*.
[3]Only the highest loadings have been given for each component.
[4]Values are the squares of the multiple correlation between each variable and others in the set.

Ceanothus velutinus Community Type and *Abies amabilis/Berberis nervosa* Association. The fourth component, accounting for 7 percent of the R-matrix variation, apparently spans an environmental range approximating the *Berberis nervosa* phase of the *Abies amabilis/Vaccinium alaskaense* Association.

General Conclusions from PCA—Several general conclusions are possible from the PCA. In view of the species groupings there is strong

coincidence with analogous groupings of some of our forest types. This is particularly so in *Abies amabilis/Rubus lasiococcus*, *Chamaecyparis nootkatensis/Vaccinium ovalifolium*, *Alnus rubra/Rubus spectabilis*, *Tsuga heterophylla/Polystichum munitum*, *Abies amabilis/Tiarella unifoliata*, and *Pseudotsuga menziesii/Xerophyllum tenax* communities. Other forest types are not so clearly revealed, but species groupings are at least suggestive of some. We feel that PCA is less effective for habitat and community type resolution than similarity analysis and plot groupings based upon tabular procedures (Shimwell 1972). One shortcoming of PCA is its limitation to species showing linearity along environmental axes. This often eliminated dominant species whose distributional modes coincide with associations and community types. On the other hand, PCA does present insights into individualistic patterns of species distribution. For example, *Rhododendron albiflorum* was shown to respond differently than *Menziesia ferruginea* along principal components at high elevations. Herbs of wet environments are separated from herbs of mesic or drier environments. We made no attempt to resolve species distances along ordination axes.

PCA gave insights into possible environmental gradients affecting species distribution. But until environmental measurements permit direct ordination, these gradients remain hypothetical. Generally, environmental factors affecting shrub cover differ or oppose those favoring herb cover. Our analyses suggested a variety of contrasting, complex environmental gradients affecting species distribution, including elevation, soil moisture, snowpack duration, and successional or microclimatic gradients. Our results also show, however, that at most only about 30 percent of the variation in the species correlation matrix can be accounted for by the principal components or gradients. This further illustrates the complexity of environmental factors affecting species distributions within each of the four major forest groupings. Some of the remaining variation in species distribution might also be reduced by use of more powerful interspecies association measures.

Chapter 7
Forest Dynamics

Change occurs constantly in forest landscapes. Disturbances and the ecological characteristics of the various tree species are responsible for most of this change. There is a continuum of disturbances, from the large, catastrophic event that destroys all or most of the old forest, to small-scale disturbances, such as an individual windthrown tree, that create much of the patchiness within established stands. Tree-species characteristics, such as their seeding habits and ability to tolerate shade, will determine how forest composition will evolve in response to these disturbance events.

In this chapter we will briefly review what is known about forest disturbance and succession in Mount Rainier National Park. We begin with considerations of large-scale disturbances, such as wildfire and volcanic events. Successional relationships of tree species and rates of forest recovery are considered next. The chapter concludes on the topic of tree mortality and patterns of small-scale disturbance in forests at Mount Rainier.

Large-Scale Disturbances

Catastophic disturbances are events that destroy most or all of the preceding forest, thereby creating conditions for establishment of a new forest stand. These infrequent events "reset" the forest to the beginning of a new successional sequence and open habitat for pioneer species. Succession is initiated with herb- and shrub-dominated communities under conditions of little or no forest canopy. New trees gradually become established, the tree canopy closes, and the forest then progresses through a series of structural and compositional changes. During stand development, species of lower shade tolerance (such as *Pseudotsuga menziesii* and *Abies procera*) are gradually replaced by more shade-tolerant tree species (such as *Abies amabilis* and *Tsuga heterophylla*).

At Mount Rainier National Park, catastrophic events have been of primary importance in creating the basic mosaic of forest patches of varying age and composition. Agents of forest destruction in the Park include wildfire, wind, volcanic events (especially lahars within recent times), snow avalanches, and floods. The frequency and distribution of many such events during the last millenium has been documented at Mount Rainier (Hemstrom and Franklin 1982).

Wildfire is, by far, the most important agent of forest catastrophe at Mount Rainier National Park, followed by snow avalanches and debris flows (lahars) (Hemstrom and Franklin 1982). Wildfires have occurred on approximately 90 percent of the existing stands, avalanches on 7 percent, and lahars on 2 percent. Small tracts of both blowdown and flooded forest are also present. While high-velocity winds can destroy extensive forested areas in the Pacific Northwest, as during the Columbus Day windstorm of 1982, wind generally appears to function as an agent of small-scale, within-stand disturbance at Mount Rainier National Park. Exceptions may be found along Park boundaries, where forests are exposed to the full force of winds by clearcutting on adjacent lands.

Fourteen major fire events have been documented since 1230 A.D. (Table 17 and Plate 2). The largest and oldest disturbance identified was a widespread fire episode in 1230 A.D. that affected about 25,000 ha of forest land in all four quarters of the Park. Stands of this 750-year age class still dominate much of the Ohanapecosh River drainage. Other episodes that affected approximately 13,000 ha of forest occurred in 1403 A.D., 1503 A.D., and 1628 A.D. The 350-year-old stands that originated following the 1628 fire are the most extensive age class of forest currently existing in Mount Rainier National Park; such forests dominate the upper slopes in the Carbon, Mowich, Puyallup, and, to a lesser extent, the Nisqually River drainages. One or more fires in 1703 A.D. resulted in the establishment of 275-year-old stands in the White and Ohanapecosh River drainages; stands of this age characterize the Ohanapecosh Campground and surrounding areas. Extensive fires that occurred in the mid to late 1800s may have been ignited by European settlers who entered the region at that time. Large portions of the Cowlitz drainage burned in 1856 and again in 1885, and the White River was subjected to a major fire in 1858. Large areas at moderate to high elevations within both of these drainages are still sparsely forested.

Fire frequency appears to be a complex issue based on the fire history reconstruction (Hemstrom and Franklin 1982). Natural fire rotation, defined as the time necessary for fires with a given frequency to burn over and reproduce an area the size of the study area, is about 465 years for the pre-European era at Mount Rainier. During early settlement, the fire rotation dropped to 226 years, perhaps because of human activity. Climatic influences appear important in creating conditions for

Table 17. Major fires, their correspondence to periods of drought, and the present and reconstructed original extent of resulting seral forests at Mount Rainier National Park (after Hemstrom and Franklin 1982).

	Present forested area		Reconstructed forested area		
Episode date (A.D.)	Hectares	Percent of total	Hectares	Percent of total	Drought period
1230	6,265	12	25,000	47	
1303	1,450	3	6,000	11	1290-95[2]
1403	6,910	13	13,700	26	1406-13[2]
1503	4,700	9	13,680	26	1477-90[2]
1628	11,060	21	12,900	24	1627-33[2]
1688	1,200	2	4,410	8	1686[3]
1703	2,700	5	5,140	10	1700[3]
1803	2,230	4	2,230	4	1801[3]
1825	2,400	5	2,480	5	1823-26[3]
1856	490	1	2,800	5	1856[3]
1858	3,040	6	3,700	7	1856[3]
1872	600	1	600	1	1869-73[2]
1886	3,800	7	4,280	8	1888[3]
1934	770	1	770	1	1917-36[2]

[1]No climatic reconstructions available for dates before 1250 A.D.
[2]Keen (1937) first- or second-magnitude drought.
[3]Blasing and Fritts (1976) abnormally dry winter.

catastrophic fire, however. Correspondence between drought events, as reconstructed from tree-ring chronologies, and fire episodes is striking (Table 17). Hence, major fires may be dependent upon unusual weather conditions and not reflect an internally induced cycle of forest susceptibility to burning.

Fire occurrence varies with topographic position, Park drainage, and habitat type (Hemstrom 1982, Hemstrom and Franklin 1982). Alluvial terraces, valley bottoms, and protected north-facing slopes have burned less frequently and are often occupied by old stands. Furthermore, nearly every major river valley contains a streamside old-growth corridor. Based on a study of fire-boundary locations within the Park, valley bottoms are, along with ridgetops, the most important natural firebreaks (Hemstrom 1982). Contrasts in forest ages between north- and south-facing slopes also occur in almost every major drainage. Within the Park the White, Cowlitz, and Nisqually River drainages have burned the most frequently. In the case of the Cowlitz and Nisqually, this may be due to a generally south aspect and lack of topographic and

vegetative barriers that might prevent fires from burning into the Park. Higher fire frequency is to be expected in the relatively dry White River drainage; natural fire rotation is 324 years for White River compared to 438 years for the Nisqually drainage (Hemstrom 1982).

Fire frequency varies rather drastically with habitat type (Table 18) (Hemstrom 1982). Much of this variation is correlated with topographic position. For example, several of the types with high fire frequency are characteristic of south slopes. Habitat types with low fire frequency are typically moist, valley-bottom sites (e.g., ABAM/OPHO) or cold, wet subalpine habitats (e.g., ABAM/RHAL).

Snow avalanches and lahars are other major forest disturbances that have been identified at Mount Rainier (Hemstrom and Franklin 1982). Approximately half of the 4270 ha of avalanche tracks are found in the White and Cowlitz River drainages. In general, large areas of snow avalanches are associated with recent burns; for example, large, complex tracks dissect the 1886 Cowlitz burn and the 1858 Crystal Mountain burn. Lahar-originated forests cover fairly small areas but occur in

Table 18. Fire frequency[1] (FF) and natural fire rotation[2] (NFR) by habitat type for Mount Rainier National Park (excluding Carbon and Puyallup River drainages) (from Hemstrom 1982).

Habitat or community type	NFR	FF	Rank
Abies lasiocarpa/Valeriana sitchensis	275	.0035	1
Abies amabilis/Berberis nervosa	295	.0034	2
Tsuga heterophylla/Achlys triphylla	308	.0033	3
Abies amabilis and *Tsuga heterophylla/ Gaultheria shallon*	313	.0032	4
Abies amabilis/Xerophyllum tenax	323	.0031	5
Abies amabilis/Menziesia ferruginea	343	.0029	6
Abies amabilis/Rubus lasiococcus/ Rubus lasiococcus phase	367	.0027	7
Abies amabilis/Tiarella unifoliata	426	.0023	8
Tsuga heterophylla/Polystichum munitum	435	.0023	9
Abies amabilis/Vaccinium alaskaense and *Chamaecyparis nootkatensis/Vaccinium ovalifolium*	474	.0021	10
Abies amabilis/Rhododendron albiflorum	478	.0021	11
Abies amabilis/Oplopanax horridum	535	.0019	12
Abies amabilis/Erythronium montanum	616	.0016	13

[1]Burned hectares per hectare of habitat type per year for fires over 100 ha.
[2]The time required to burn an area equal to the total area of each habitat type given its burn rate.

all of the major river drainages. The 1947 Kautz Creek lahar provides one of the most recent and obvious examples of a regenerating debris flow; young forests of *Alnus rubra* and conifers are typical of the deposits.

Despite extensive catastrophic disturbances, forests at several locations around Mount Rainier have survived for over 1,000 years with no evidence of disturbance (Plate 2). These ancient forests grow in protected valley bottoms throughout the Park and on slopes in the Ipsut and Cataract Creek drainages, tributaries of Carbon River. Except for avalanches and a small burn in the upper reaches of the valley, the forests of the Ipsut Creek valley apparently have been free of major disturbances for over 1,200 years based on estimated ages of the large *Chamaecyparis nootkatensis* found there. Forests along Cataract Creek appear similar to those of Ipsut Creek but lack the *Chamaecyparis*; early seral trees are absent, and there is no evidence of catastrophic disturbance in the lower valley for well over 1,000 years. Other stands estimated as being over 1,000 years of age are found near the confluence of the Ohanapecosh River and Chinook Creek, in the upper Cowlitz River basin, and near Cougar Rock Campground in the Nisqually River drainage. The latter stand appears to be the first generation of forest on a portion of the Paradise lahar assemblage (Crandell 1971); trees have grown very slowly on this nutrient-poor substrate.

Successional Sequences

Occurrence and successional roles of the major tree species at Mount Rainier vary with moisture and temperature conditions (Table 19). The most shade-tolerant species occurring on a habitat type are usually considered to be the potential climax species, i.e., capable of maintaining themselves on the site in the absence of major disturbance. Tree species that are intolerant of shade and require a major disturbance for reproduction are considered to be seral. However, it is important to note that climax species often reproduce immediately following a disturbance and can play a major role in early successional forests in a moist, cool region such as Mount Rainier.

Pseudotsuga menziesii is the major seral species and *Tsuga heterophylla* is the major climax species in communities belonging to the *Tsuga heterophylla* Series at Mount Rainier (Table 19). *Abies grandis* also plays a minor successional role, as does *Alnus rubra* on moister habitat types. Interpretation of the role of *Thuja plicata* is difficult, but we have tentatively assigned it dual roles as a major seral and minor climax species: a major climax role could be argued based on its low mortality rate (see following section) and long life span, factors that should result in increasing stand representation for *Thuja* over long periods free from major disturbances.

Table 19. Successional roles for major tree species on habitat types in Mount Rainier National Park; s = minor seral species, S = major seral species, c = minor climax species, and C = major climax species.

	Habitat type[1]													
Species	TSHE/ ACTR	TSHE/ POMU	TSHE/ OPHO	ABAM/ OPHO	ABAM/ TIUN	ABAM/ VAAL	TSHE/ GASH	ABAM/ GASH	ABAM/ BENE	ABAM/ XETE	ABAM/ RULA	ABAM/ RHAL	CHNO/ VAOV	ABAM/ MEFE
Abies amabilis	c	c	c	C	C	C	c	C	C	C	C	C	C	C
Abies grandis	S	s	s	s			s							
Abies lasiocarpa									s	s	S		s	s
Abies procera	s			s	S	s	s	s	s	S	s	s	s	s
Alnus rubra		s	s	s										
Chamaecyparis nootkatensis				s	c	c		c	s	c	Sc	SC	C	Sc
Picea engelmanii				s	s				s		s		s	s
Picea sitchensis			s											
Pinus albicaulis											s			
Pinus contorta									s	s	s			
Pinus monticola	s				s	s	s	s	s	s	s	s	s	s
Pseudotsuga menziesii	S	S	S	s	s	S	S	S	S	S	s	s		s
Thuja plicata	c	Sc	Sc	Sc	s	Sc	c	c	c	s		s	s	c
Tsuga heterophylla	C	C	C	Sc	c	Sc	C	c	C	Sc	s	s	c	Sc
Tsuga mertensiana					s	s				Sc	Sc	Sc	Sc	Sc

[1]TSHE/ACTR = *Tsuga heterophylla/Achlys triphylla*, TSHE/POMU = *Tsuga heterophylla/Polystichum munitum*, TSHE/OPHO = *Tsuga heterophylla/ Oplopanax horridum*, ABAM/OPHO = *Abies amabilis/Oplopanax horridum*, ABAM/TIUN = *Abies amabilis/Tiarella unifoliata*, ABAM/VAAL = *Abies amabilis/Vaccinium alaskaense*, TSHE/GASH = *Tsuga heterophylla/Gaultheria shallon*, ABAM/GASH = *Abies amabilis/Gaultheria shallon*, ABAM/ BENE = *Abies amabilis/Berberis nervosa*, ABAM/XETE = *Abies amabilis/Xerophyllum tenax*, ABAM/RULA = *Abies amabilis/Rubus lasiococcus*, ABAM/RHAL = *Abies amabilis/Rhododendron albiflorum*, CHNO/VAOV = *Chamaecyparis nootkatensis/Vaccinium ovalifolium*, ABAM/MEFE = *Abies amabilis/Menziesia ferruginea*.

The *Abies amabilis* Series can be divided into lower and higher elevation segments based on the major *Tsuga* associate (Table 19).

Abies amabilis is the major climax species throughout. At lower elevations *Tsuga heterophylla* is a major early successional species and a minor climax species and *Pseudotsuga menziesii* is a major seral species. *Abies procera* is a seral species of varying importance depending upon habitat type. *Pinus monticola* is widespread and can be locally abundant in young and mature stands. *Thuja plicata* is generally interpreted as a minor climax species on lower elevation *Abies amabilis* habitats.

Tsuga mertensiana is the major early successional species and a minor climax component on higher and colder *Abies amabilis* habitats (Table 19). *Abies procera, Abies lasiocarpa, Pinus monticola*, and *Picea engelmannii* are typical early successional species, although low-elevation species such as *Tsuga heterophylla, Thuja plicata*, and *Pseudotsuga menziesii* may also be represented. The successional role of *Chamaecyparis nootkatensis* presents problems in interpretation similar to those for *Thuja plicata*; it is often abundant within stands (hence has a major early successional role), but *Chamaecyparis* also appears capable of effectively reproducing itself in small numbers and surviving to very old ages.

Few data are available on rates of forest recovery following catastrophic disturbance as compared with our knowledge of patterns of change in forest structure and composition. Rates of recovery are dependent upon many variables, including availability of seed, severity of the post-disturbance environment, and amount of competing vegetation. Recovery can be rapid following small- to medium-sized disturbances on habitats with moderate environments; abundant wind-dispersed seeds are available from surrounding areas of undamaged forest and moisture and temperature conditions are favorable to plant establishment. In such circumstances, reestablishment of forest trees and development of a closed forest canopy can be expected in 20 to 30 years. Competing herb and shrub vegetation can retard forest reestablishment on the most productive (warm and moist) habitats characterized by species such as *Athyrium* and *Oplopanax* even in relatively small disturbance areas.

Forest recovery can be especially slow following a large-scale disturbance or a disturbance on environmentally stressful sites. Single wildfires on low- to middle-elevation forest sites often cause rapid regeneration even when they cover large areas; this results from the patchy nature of such wildfires, which often leave individual, groups, and even large patches of streamside corridors of live trees as seed sources (Franklin and Dyrness 1973). Multiple burns of the same area can severely retard forest regeneration, however, by eliminating more and more of the seed source and stimulating competing shrub and herbaceous vegetation. As a consequence, areas subject to multiple wild-

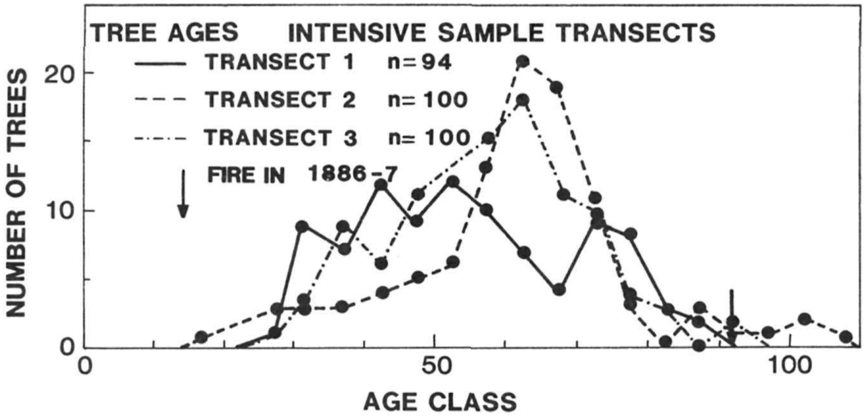

Figure 38. Age-class distribution of trees in stands developed following wildfires in the later 1800's in the Cowlitz River drainage, Mount Rainier National Park, Washington (from Hemstrom, 1979).

fires can take many decades or even a century to completely regenerate. For example, *Pseudotsuga, Pinus*, and *Abies procera* were still becoming established in the 1886 Cowlitz Burn more than 75 years after the last fire (Hemstrom and Franklin 1982) (Fig. 38). Delayed patterns of regeneration and multiple burns can result in old-growth stands that demonstrate very wide age ranges in the *Pseudotsuga* dominants (Franklin and Hemstrom 1981).

Areas of burned forest at high elevations may also regenerate very slowly, after a single burn and with abundant seed available. Examples can be seen along the Stevens Canyon Road below Mirror Lake and on Crystal Mountain. Such slow regeneration is a consequence of severe site conditions; competing vegetation and animal predation can also be factors in high-elevation burns. Regeneration of some high-elevation sites may need to await a climatic episode that favors tree regeneration, similar to conditions that led to extensive invasion of subalpine meadows early in this century (Franklin et al. 1967).

Tree Mortality and Small-Scale Disturbances

Small-scale disturbances and tree death are important in creating more heterogenous or variable forest conditions. Death of individual or small groups of trees creates critical structures—snags and down logs—that fulfill important wildlife and nutrient conservation functions (Harmon et al. 1986, Brown 1985). Mechanical effects, such as the effects of tree uprooting on soil mixing, are also important. Therefore, knowledge of rates and patterns of tree death are valuable in understanding how forest ecosystems function.

Much tree death in the forests of the Pacific Northwest occurs as a result of small-scale disturbances. Such disturbances include small patches or gaps created by windthrow and openings created by contagious diseases, such as the root rot *Phellinus weirii*, or bark beetles, such as *Dendroctonus* spp. Mortality of this type may occur continuously or as episodes. Episodes often occur when stands have excess numbers of trees and are subsequently subjected to an environmental stress that renders them more susceptible to beetle or pathogen attack.

Tree mortality has been studied in mature and old-growth forests at Mount Rainier.[3] Data were collected from permanent sample plots that have been established in 17 stands representing 13 of the community types described in this monograph; 13 of the plots are in old-growth forest (250 to 1,200 years of age) and 4 are in mature stands (90 to 150 years of age).

Tree mortality averaged 0.52 percent annually over a 10-year period in mature and old-growth forests, indicating a relatively dynamic condition (see footnote 3). Annual rates have fluctuated between 0.27 and 0.86 percent per annum. Major causes of tree mortality are suppression (25.3 percent), unknown (24.6 percent), crushing by falling tree (22.8 percent), windbreak (9.1 percent), and windthrow or uprooting (8.8 percent). Disease, insects, and miscellaneous causes make up the remainder.

Rates of mortality varied widely with species. Surprisingly, *Pseudotsuga, Tsuga heterophylla*, and *Abies amabilis* had comparable rates of mortality (0.57, 0.48, and 0.52 percent per annum). *Abies procera* had a much higher rate than other common conifers (0.95 percent) for unknown reasons. *Thuja plicata* and *Chamaecyparis nootkatensis* had low rates of mortality (0.17 and 0.23 percent per annum). These low rates suggest that *Thuja* and *Chamaecyparis* may increase their representation within the forests even though relatively few seedlings and saplings are produced compared to the *Tsuga* and *Abies*.

Rates of mortality also varied dramatically with habitat type and with forest age class (see footnote 3). More productive sites tended to have higher rates of mortality. Three old-growth stands on *Oplopanax horridum* sites averaged 1.08 percent mortality per annum, over twice the average for all plots. Similarly, mature stands (considered to be stands between 100 and 200 years of age) averaged nearly twice the rate for old-growth stands on the same habitat types; such stands are probably still experiencing stand thinning due to competition, the primary cause of mortality in young forest stands.

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[3]Unpublished manuscript in technical review. "Tree mortality in some mature and old-growth forests in the Cascade Range of Oregon and Washington," by Jerry F. Franklin, Mark Klopsch, Karen J. Luchessa, and Mark E. Harmon. 35 p., 1987. On file at Forestry Sciences Laboratory, Corvallis, Oregon.

These data on mortality, along with those from natural forest stands elsewhere in the Pacific Northwest, indicate that tree populations are quite dynamic in mature and old-growth forests such as those at Mount Rainier (see footnote 3). Continuing, modest levels of tree mortality are to be expected, as are occasional episodes with rates up to perhaps 10 times the normal background levels. The basic forest size structure is apparently maintained through such events, and compositional changes occur only very slowly due to low rates of mortality in large, old *Pseudotsuga* and *Thuja*, for example.

The gaps or openings created in the forest by tree death and small-scale disturbance at Mount Rainier are too small to allow successful regeneration of the major pioneer species, such as *Pseudotsuga*. The majority of the mortality occurs as single individuals, and near simultaneous death of more than a half-dozen trees in a small group is very rare. This is a significant ecological feature of the northwestern forests. Small forest gaps are considered to be an important mechanism for perpetuating shade-intolerant tree species in the hardwood forests of eastern North America. At Mount Rainier, the openings are rarely of sufficient size (perhaps 35 m in diameter) to allow reproduction of major shade-intolerant species. Furthermore, forest gaps are typically already occupied by seedlings and saplings of *Tsuga*, *Abies*, and *Thuja*, which utilize the newly available resources. Hence, the shade-intolerant species at Mount Rainier National Park appear to depend upon larger scale disturbances to create suitable conditions for their regeneration.

Chapter 8
Management Interpretations of the Habitat Types

A major objective of community or habitat type classifications is the development and extrapolation of information on management problems and development potential. Because areas identified as belonging to the same habitat type are viewed as having comparable environments, responses to specific management practices should be similar. Hence, it is reasonable to extrapolate management experience or research results from one area of the same habitat type to another.

Qualitative data on characteristics relevant to management, such as productivity and soil drainage, were collected during the development of the habitat type classification at Mount Rainier. Although quantitative information and detailed studies of effects of various practices or uses stratified by habitat type would be desirable, the qualitative data provide some guidance on the potential of different habitat types for Park use and development.

Some characteristics of the Mount Rainier habitat types relevant to National Park Service management are summarized in Table 20. Each characteristic will be discussed briefly in the following paragraphs. The reader should note that these are broad, qualitative characterizations. Detailed, quantitative data on management characteristics of community types, such as productivity and wildlife potential, are being collected on the Gifford Pinchot and Mt. Baker-Snoqualmie National Forest lands adjacent to the Park (Henderson and Peter 1981, Brockway et al. 1983). This large body of information should be generally applicable to the community types within the Park.

Physical Conditions

The three factors considered under physical conditions are length of growing season, soil drainage, and depth and duration of snowpack.

Table 20. Management-related features of the various forest habitat types at Mount Rainier National Park.

	Physical conditions			Biological conditions			Natural disturbances			Development potential		
Habitat type[1]	Growing season[2]	Drainage[3]	Snowpack[4]	Productivity[5]	Plant diversity[6]	Wildlife[7]	Specimen trees[8]	Fire[9]	Pathogen[10]	Wind[11]	Resistance[12]	Resilience[13]
TSHE/ACTR	L	W	I	H	M	OG,U,A		M-H	BB		L	M
TSHE/POMU	L	W	I	VH	M	OG,U,A	P	L		H	L	H
TSHE/OPHO	L	W-P	I	VH	H	OG,U,A	P	L		H	M	H
ABAM/OPHO	M	W-P	M	H	H	OG,U,A	P	L		H	M	H
ABAM/TIUN	M	W	M-D	VH	H		P	M			L	M
ABAM/VAAL	M	W	M	M	M	OG	P	L			H	M
TSHE/GASH	L	E-W	I	L	L	U		H	DM		H	L
ABAM/GASH	M	E-W	M	L	L			H	DM		H	L
ABAM/BENE	M	W	M	M	L			H	BB		M	M
ABAM/XETE	M	W	M-D	M-L	L			H	BB		H	M
ABAM/RULA (RULA)	S	W	D	M-L	M(H)			M			M	M
ABAM/RULA (ERMO)	S	W	D	M-L	M(H)			L			M	M
CHNO/VAOV	S	P	M-D	L	M-H	A		L		H	M	L
ABAM/RHAL	S	P	D	L	M		P	L		H	M	L
ABAM/MEFE	S	P	D	M-L	M			M			M	M
PSME/ARUV	M	E	I-M	VL	M			H	DM		L	L

[1]TSHE/ACTR = *Tsuga heterophylla/Achlys triphylla*, TSHE/POMU = *Tsuga heterophylla/Polystichum munitum*, TSHE/OPHO = *Tsuga heterophylla/Oplopanax horridum*, ABAM/OPHO = *Abies amabilis/Oplopanax horridum*, ABAM/TIUN = *Abies amabilis/Tiarella unifoliata*, ABAM/VAAL = *Abies amabilis/Vaccinium alaskaense*, TSHE/GASH = *Tsuga heterophylla/Gaultheria shallon*, ABAM/GASH = *Abies amabilis/Gaultheria shallon*, ABAM/BENE = *Abies amabilis/Berberis nervosa*, ABAM/XETE = *Abies amabilis/Xerophyllum tenax*, ABAM/RULA (RULA) = *Abies amabilis/Rubus lasiococcus*, ABAM/RULA (ERMO) = *Abies amabilis/Erythronium montanum*, CHNO/VAOV = *Chamaecyparis nootkatensis/Vaccinium ovalifolium*, ABAM/RHAL = *Abies amabilis/Rhododendron albiflorum*, ABAM/MEFE = *Abies amabilis/Menziesia ferruginea*, PSME/ARUV = *Pseudotsuga menziesii/Arctostaphylos uva-ursi*.

[2]Ratings are: L = long, M = medium, S = short growing season.

[3]Ratings are: E = excessively, W = well, P = poorly drained soil conditions.

[4]Ratings are: I = intermittent, M = moderately deep, D = deep snowpack.

[5]Ratings are: VL = very low, L = low, M = moderate, H = high, and VH = very high productivity.

[6]Ratings are: L = low, M = moderate, H = high diversity, (H) = high density in early successional communities.

[7]Symbols are: OG = important to temperate, old-growth animal species, U = ungulate winter habitat, A = important amphibian habitat.

[8]P = presence of unusually large or old trees.

[9]Ratings are: L = low, M = moderate, H = high fire frequency.

[10]Symbols are: BB = bark beetles, DM = dwarf mistletoe as important pests.

[11]Symbol is: H = high potential for windthrow.

[12]Resistance refers to the ecosystem's ability to withstand impacts; L = low, M = moderate, H = high resistance.

[13]Resilience refers to the ecosystem's ability to recover after a major disruption; L = low, M = moderate, H = high resilience.

These features are obviously relevant to management, for appraising the development potential of a particular site for a campground or trail, for example.

Growing season can be measured in a variety of ways, but one common method in the Pacific Northwest is a scheme for summing temperatures over a given threshold, referred to as the "growing season temperature growth index" (GSTGI) (Greene and Klopsch 1985). Temperature data gathered from a few stands (Greene and Klopsch 1985) allow us to scale the qualitative ratings shown in Table 20: long growing seasons have GSTGI values of from 55 to 65, medium growing seasons have values from 40 to 60, and short growing seasons have values from 25 to 50. Note that any measure of growing season, whether by temperature growth index or frost-free period, will vary substantially from year to year. Sites with long and medium growing seasons typically have over 290 frost-free days, whereas those with short growing seasons have 200 to 290 days (Greene and Klopsch 1985).

Soil-drainage ratings are based on observations of conditions within soil pits dug in each habitat type. Excessive drainage indicated coarse-textured soils that have low water-holding capacity; droughty conditions are normally expected on such sites. Well-drained sites have no features suggesting poor or excessive soil drainage. Poorly drained soils have morphological features indicating poor drainage, such as gleyed soil horizons, and soil pits sometimes contained standing water due to perched water tables.

Three ratings are provided for depth and duration of snowpack (Table 20). *Tsuga heterophylla* habitat types are shown as having an intermittent snowpack; that is, the snowpack will typically come and go during the course of a normal winter. The bulk of the *Abies amabilis* Zone has a moderate snowpack, a permanent winter snowcover that will typically reach depths of 1 to 2 m. Deep snowcover refers to areas with a permanent winter snowpack that attains depths of 2 to 5 m or more and persists until late June or July. Approximate values for average winter snow depth can be obtained by observing the growth of lichens on tree trunks; most of the larger foliose species are unable to grow at heights where they are subject to extensive snow burial.

Biological Conditions

Factors rated under biological conditions are productivity, plant diversity, potential for specialized wildlife, and occurrence of specimen trees or groves (Table 20).

Site productivity can be indexed in a variety of ways, but the only quantitative measure available from this study is site index, the height to which dominant trees grow during a given period of time. All of the

habitat types with high or very high productivity ratings are on moist to wet sites at low to middle elevations (Table 20); productivity generally approximates a Site Class I or II for *Pseudotsuga* and Class I for *Abies procera*. Sites of medium productivity approximate a Site Class III or IV for *Pseudotsuga* and II and III for *Abies procera*. Low productivity sites approximate a *Pseudotsuga* Site Class V or *Abies procera* Site Class IV. Productivity is so low on the *Pseudotsuga menziesii/ Arctostaphylos uva-ursi* sites that forests often lack a closed tree canopy.

Plant diversity ratings are based on the numbers of vascular plant species typically found within forest stands growing on each habitat type. Moist, lower elevation habitats typically contain the largest number of species. In at least some other parts of the Northwest, dry habitats also tend to have high diversity (e.g., Zobel et al. 1976); this is not the case at Mount Rainier, where the driest forest habitats are typically the depauperate *Gaultheria shallon* types (Table 20). Relatively high species diversity is also encountered on the *Chamaecyparis nootkatensis/Vaccinium ovalifolium* Habitat Type, which typically includes boggy areas within a forest matrix. Very rich, meadow-like communities characterize early successional stages on the *Abies amabilis/ Rubus lasiococcus* Habitat Type; the diversity of these communities contrasts with the moderate levels of diversity typical of closed forest stands on the same habitat type.

Special wildlife features considered include occurrence of old-growth species, winter habitat for ungulates (elk and deer), and habitat for amphibians (Table 20). Temperate old-growth forests in the Pacific Northwest have been identified as the preferred (and, in some cases, essential) habitat for an array of bird, mammal (including bat), and amphibian species (Franklin et al. 1981). Much of the forest at low to middle elevations within Mount Rainier National Park is excellent habitat for these old-growth-related wildlife. Extensive areas of appropriate age classes and forest structures are present, and suitable habitat types included the very widespread *Abies amabilis/Vaccinium alaskaense* type. Detailed studies of vertebrate populations in old-growth as well as younger forests are currently underway and should provide much additional information on their distribution within the Park. The most prominent winter habitats for ungulates are the productive, valley-bottom habitat types, although the relatively warm and dry *Tsuga heterophylla/ Gaultheria shallon* habitat also receives considerable use. Amphibians are most common on habitat types normally associated with water bodies that are essential to their reproduction.

Trees or groves of trees of unusual size and age are of special interest to the visitor; these usually occur in old-growth stands on high productivity habitat types (Table 20). The *Oplopanax* and *Polystichum* habitats are primary sites for outstanding specimens of *Pseudotsuga menziesii*

and *Thuja plicata*, for example (Fig. 39). The largest *Tsuga heterophylla* and *Abies amabilis* will also be found there. Superlative specimens of *Abies procera* are encountered on the *Abies amabilis/Tiarella* Habitat Type. Some of the most impressive specimens of *Chamaecyparis nootkatensis* will actually be found on a low productivity habitat type, the *Abies amabilis/Rhododendron albiflorum* (Table

Figure 39. Superlative specimen trees of *Pseudotsuga* and *Thuja* are characteristic of the moist, alluvial and lower slope habitat types.

20). Specimen trees are also found on the very widespread *Abies amabilis/Vaccinium alaskaense* Habitat Type.

Potential for Disturbances

Potential disturbances to forests from wildfire, insects and plant diseases, and wind vary by habitat type (Table 20).

Important correlations may exist between fire frequency and habitat type as discussed in the previous chapter (Table 20) (Hemstrom 1982). Low-risk habitat types are those occurring on moist habitats that are, in turn, generally located in valley-bottom environments. These include the two *Oplopanax, Polystichum*, and *Vaccinium alaskaense* Habitat Types. Habitat types that characterize warmer, drier environmental conditions, such as the *Gaultheria, Berberis*, and *Xerophyllum* types, have substantially higher fire frequencies. Most of the high-elevation types have moderate levels of fire risk. The *Abies lasiocarpa/Valeriana sitchensis* Community Type is a significant exception; this community has the highest fire frequency (275 years) of any type studied in the Park (Hemstrom 1982).

Many forest insects and plant diseases will probably prove to be correlated with vegetation types once detailed studies have been conducted. Little information is currently available, however (Table 20). *Gaultheria* habitats were noted as having high levels of dwarf mistletoe (*Arceuthobium* spp.), especially in the *Tsuga heterophylla*. Some other habitats appeared to have higher levels of bark beetles (*Dendroctonus* spp.) in *Pinus* spp. and *Pseudotsuga menziesii*.

Natural windthrow is highest on habitat types that have moist to wet soils. Uprooting of trees has been observed as common on permanent sample plots in *Oplopanax* types (see footnote 3). Sites with high water tables at high elevations are also more vulnerable to uprooting.

Development Potential

Habitat types are rated for development potential (e.g., camping areas and trails) on the basis of their resistance and resilience. Resistance refers to the ability of a habitat to tolerate human impacts, such as trampling, without undergoing major changes in community composition and structure. Resistance generally reflects the "toughness" of the vegetative cover. Resilience refers to the ability of vegetation on a habitat to recover once it has been destroyed or severely disrupted. Resilience often reflects the inherent productivity of a habitat.

Communities on high productivity sites dominated by herbaceous understories (TSHE/OINYM, TSHE/ACTR, and ABAM/TIUN) tend to have low resistance and high resilience. Understories are easily

damaged by human use due to the fragility of many species but have inherently high rates of recovery. The *Oplopanax* communities are somewhat more resistant to use because of durable shrub layers that also tend to discourage human movement.

The bulk of the communities at Mount Rainier have moderate to high levels of resistance to developmental impacts and moderate to low levels of resilience (Table 20). This is because the shrubby ericaceous understories are generally composed of species that can tolerate moderate impact levels. Once destroyed, however, recovery can be relatively slow due to slow reestablishment and growth of plants. This is a particularly serious problem on sites that have deep, persistent snowpacks (e.g., CHNO/VAOV and ABAM/RHAL). Sites on glacial outwash and lahars, including PSME/ARUV habitats, typically have understories that include species easily damaged by trampling (e.g., lichens and mosses) and very low rates of recovery due to severe site conditions. Longmire Campground provides an example of such a habitat.

Literature Cited

BLASING, T. J., and H. C. FRITTS. 1976. Reconstructing past climatic anomalies in the North Pacific and western North America from tree ring data. *Quaternary Res.* 10:563–579.

BROCKMAN, C. F. 1931. Forest and timber types of Mount Rainier National Park. M.F. Thesis. Univ. Washington, Seattle. 54 pp.

BROCKMAN, C. F. 1933. The forests of Mt. Rainier. *Nat. Hist.* 33:523–532.

BROCKMAN, C. F. 1947. Flora of Mount Rainier National Park. U.S. Dept. Inter., Washington, D.C. 170 pp.

BROCKMAN, C. F. 1949. Trees of Mount Rainier National Park. Univ. Washington Press, Seattle. 49 pp.

BROCKWAY, D. G., C. TOPIK, M. A. HEMSTROM, and W. H. EMMINGHAM. 1983. Plant association and management guide for the Pacific Silver Fir Zone Gifford Pinchot National Forest. U.S. Dept. Agric., For. Serv., Pac. Northwest Reg., Portland, Oregon. 122 p.

BROOKE, R. C., E. G. PETERSON, and V. J. KRAJINA. 1970. The subalpine mountain hemlock zone. Pages 147–349 *in* V. J. Krajina, ed., Ecology of western North America. Univ. British Columbia, Dept. Botany, Vancouver, B.C. Vol. 2.

BROWN, E. R. 1985. Management of wildlife and fish habitats in forests of western Oregon and Washington. U.S. Dept. Agric., For. Serv., Pac. Northwest Reg., Portland, Oregon. Part 1. 332 pp. Part 2. 302 pp.

COOLEY, W. W., and P. R. LOHNES. 1971. Multivariate data analysis. John Wiley and Sons, New York. 364 pp.

CRANDELL, D. R. 1969. Surficial geology of Mount Rainier National Park, Washington. U.S. Dept. Inter., Geological Survey Bull. 1288. U.S. Govt. Printing Office, Washington, D.C. 41 pp.

CRANDELL, D. R. 1971. Postglacial lahars from Mount Rainier volcano, Washington. U.S. Dept. Inter., Geological Survey Prof. Pap. 677. U.S. Govt. Printing Office, Washington, D.C. 75 pp.

CRANDELL, D. R., and R. D. MILLER. 1974. Quaternary stratigraphy and the extent of glaciation in the Mount Rainier National Park region, Washington. U.S. Dept. Inter., Geological Survey Prof. Pap. 847. U.S. Govt. Printing Office, Washington, D.C. 59 pp.

CUSHMAN, M. J. 1981. The influence of recurrent snow avalanches on vegetation patterns in the Washington Cascades. Ph.D. Dissertation. Univ. Washington, Seattle. 175 pp.

DAUBENMIRE, R. 1966. Vegetation: identification of typal communities. *Science* 151:291–298.

DAUBENMIRE, R. 1978. Plant geography with special reference to North America. Academic Press, New York. 338 pp.

DAUBENMIRE, R., and J. B. DAUBENMIRE. 1968. Forest vegetation of eastern Washington and northern Idaho. Tech. Bull. 60. Washington State Agricultural Experiment Station, Seattle. 104 pp.

DEL MORAL, R., and J. N. LONG. 1977. Classification montane forest community types in the Cedar River drainage of western Washington, U.S.A. *Can. J. For. Res.* 7(2):217–225.

DEL MORAL, R., and A. F. WATSON. 1978. Gradient structure of forest vegetation in the central Washington Cascades. *Vegetation* 38(1):29–48.

DEL MORAL, R., A. F. WATSON, and R. S. FLEMING. 1976. Vegetation structure in the Alpine Lakes region of Washington State: classification of vegetation on granitic rocks. *Syesis* 9:291–316.

DYRNESS, C. T., J. F. FRANKLIN, and W. H. MOIR. 1974. A preliminary classification of forest communities in the central portion of the western Cascades of Oregon. Conif. For. Biome Bull. 4. Univ. Washington, College of Forest Resources, Seattle. 123 pp.

EDWARDS, O. M. 1980. The alpine vegetation of Mount Rainier National Park: structure, development and constraints. Ph.D. Thesis. Univ. Washington, Seattle. 280 pp.

FISKE, R. S., C. HOPSON, and A. C. WATERS. 1963. Geology of Mount Rainier National Park, Washington. U.S. Dept. Inter., Geological Survey Prof. Pap. 444. U.S. Govt. Printing Office, Washington, D.C. 93 pp.

FONDA, R. W., and L. C. BLISS. 1969. Forest vegetation of the montane and subalpine zones, Olympic Mountains, Washington. *Ecol. Monogr.* 39(3):271–301.

FOSTER, A. S. 1911. Some botanical observations in the mountains of Washington. *Plant World* 14:222–227.

FRANKLIN, J. F. 1966. Vegetation and soils in the subalpine forests of the southern Washington Cascade Range. Ph.D. Dissertation. Washington State Univ., Pullman. 132 pp.

FRANKLIN, J. F., and N. A. BISHOP. 1969. Notes on the natural history of Mount Rainier National Park. Mount Rainier Natural History Association, Longmire, Washington. 24 pp.

FRANKLIN, J. F., K. CROMACK, JR., W. DENISON, A. MCKEE, C. MASER, J. SEDELL, F. SWANSON, and G. JUDAY. 1981. Ecological characteristics of old-growth Douglas-fir forests. Gen. Tech. Rep. PNW-118. U.S. Dept. Agric., For. Serv., Pac. Northwest For. and Range Exp. Stn., Portland, Oregon. 48 pp.

FRANKLIN, J. F., and C. T. DYRNESS. 1973. Natural vegetation of Oregon and Washington. Gen. Tech. Rep. PNW-8. U.S. Dept. Agric., For. Serv., Pac. Northwest For. and Range Exp. Stn., Portland, Oregon. 417 pp.

FRANKLIN, J. F., C. T. DYRNESS, and W. H. MOIR. 1970. A reconnaissance method for forest site classification. *Shinrin Richi* 12(1):1–14.

FRANKLIN, J. F., and M. A. HEMSTROM. 1981. Aspects of succession in the coniferous forests of the Pacific Northwest. Pages 219–229 *in* D. C. West, H. H. Shugart, and D. B. Botkin, eds., Succession—concepts and applications. Springer-Verlag, New York.

FRANKLIN, J. F., and R. G. MITCHELL. 1967. Successional status of subalpine fir in the Cascade Range. Res. Pap. PNW-46. U.S. Dept. Agric., For. Serv., Pac. Northwest For. and Range Exp. Stn., Portland, Oregon. 16 pp.

GAUCH, H. G., JR. 1982. Multivariate analysis in community ecology. Cambridge University Press, Cambridge. 298 pp.

GREENE, S., and M. KLOPSCH. 1985. Soil and air temperatures for different habitats in Mount Rainier National Park. Res. Pap. PNW-342. U.S. Dept. Agric., For. Serv., Pac. Northwest For. and Range Exp. Stn., Portland, Oregon. 50 pp.

HAMANN, M. J. 1972. Vegetation of alpine and subalpine meadows of Mount Rainier National Park, Washington. M.S. Thesis. Washington State Univ., Pullman. 120 pp.

HARMON, M. E., J. F. FRANKLIN, F. J. SWANSON, P. SOLLINS, S. V. GREGORY, J. D. LATTIN, N. H. ANDERSON, S. P. CLINE, N. G. AUMEN, J. R. SEDELL, G. W. LIENKAEMPER, K. CROMACK, JR., AND K. W. CUMMINS. 1986. Ecology of coarse woody debris in temperate ecosystems. Pages 133–302 *in* A. MacFadyen and E. D. Ford, eds., Advances in ecological research. Academic Press, New York. Vol. 15.

HEMSTROM, M. A. 1979. A recent disturbance history of forest ecosystems at Mount Rainier National Park. Dissertation. Oregon State Univ., Corvallis. 66 pp.

HEMSTROM, M. A. 1982. Fire in the forest of Mount Rainier National Park. Pages 121–125 *in* E. E. Starkey, J. F. Franklin, and Jean W. Matthews, eds., Ecological research in the Pacific Northwest. Oregon State Univ., For. Res. Lab, Corvallis.

HEMSTROM, M. A., W. H. EMMINGHAM, N. M. HALVERSON, S. E. LOGAN, and C. TOPIK. 1982. Plant association and management guide for the Pacific Silver Fir Zone, Mt. Hood and Willamette National Forest. R-6-Ecol 100–1982a. U.S. Dept. Agric., For. Serv., Pac. Northwest Reg., Portland, Oregon. 104 pp.

HEMSTROM, M. A., and J. F. FRANKLIN. 1982. Fire and other disturbances of the forests in Mount Rainier National Park. *Quaternary Res.* 18:32–51.

HENDERSON, J. A. 1973. Composition, distribution and succession of subalpine meadows in Mount Rainier National Park, Washington. Ph.D. Thesis. Oregon State Univ., Corvallis. 150 pp.

HENDERSON, J. A. 1978. Plant succession on the *Alnus rubra/Rubus spectabilis* habitat type in western Oregon. *Northwest Sci.* 52:156–167.

HENDERSON, J. A., and D. PETER. 1981. Preliminary plant associations and habitat types of the White River Ranger District, Mt. Baker-Snoqualmie National Forest. U.S. Dept. Agric., For. Serv., Pac. Northwest Reg., Portland, Oregon. 60 pp.

HENDERSON, J. A., and D. PETER. 1985. Preliminary plant associations and habitat types of the Mt. Baker Ranger District, Mt. Baker-Snoqualmie National Forest. U.S. Dept. Agric., For. Serv., Pac. Northwest Reg., Portland, Oregon. 60 pp.

HIGINBOTHAM, N., and B. W. HIGINBOTHAM. 1954. Quantitative relationships of terrestrial mosses with some coniferous forests at Mount Rainier National Park. Butler Univ. Bot. Stud. 11:149–168.

HOBSON, F. D. 1976. Classification system for the soils of Mount Rainier National Park. M.S. Thesis. Washington State Univ., Pullman. 79 pp.

KEEN, F. P. 1937. Climatic cycles in eastern Oregon as indicated by tree rings. *Monthly Weather Review* 65:175–188.

KELSEY, C. T., F. G. GOFF, and D. FIELDS. 1977. Theory and analysis of vegetation pattern. Publ. 922. Oak Ridge National Laboratory, Environmental Science Division, Oak Ridge, Tennessee. 167 pp.

KOTOR, J. 1972. Ecology of *Abies amabilis* in relation to its altitudinal distribution and in contrast to its common associate *Tsuga heterophylla*. Dissertation. Univ. Washington, Seattle. 171 pp.

KRAJINA, V. J. 1965. Biogeoclimatic zones and classification of British Columbia. Pages 1–17 *in* V. J. Krajina, ed., Ecology of western North America. Univ. British Columbia, Dept. Botany, Vancouver, B.C. Vol. 1.

LAYSER, E. F., and G. H. SCHUBERT. 1979. Preliminary classification for the coniferous forest and woodland series of Arizona and New Mexico. Res. Pap. RM-208. U.S. Dept. Agric., For. Serv., Rocky Mountain For. and Range Exp. Stn., Fort Collins, Colorado. 27 pp.

LONG, J. N. 1976. Forest vegetation dynamics within the *Abies amabilis* zone of a western Cascades watershed. Dissertation. Univ. Washington, Seattle. 175 pp.

LUCKMAN, B. H. 1978. Geomorphic work of snow avalanches in the Canadian Rocky Mountains. *Arctic and Alpine Res.* 10:261–276.

MOIR, W. H. 1986. The forests of Mount Rainier: a natural history. Pacific Northwest National Parks and Forests Association, Seattle, Washington. Unpublished manuscript.

MOIR, W. H., F. D. HOBSON, M. HEMSTROM, and J. F. FRANKLIN. 1979. Forest ecosystems of Mount Rainier National Park. Pages 201–207 *in* Proceedings, 1st conference on scientific research in the National Parks. U.S. Dept. Inter., National Park Serv., Washington, D.C.

MULLINEAUX, D. R. 1974. Pumice and other pyroclastic deposits in Mount Rainier National Park, Washington. U.S. Dept. Inter., Geological Survey, Washington, D.C. 83 pp.

NIE, N. H., C. H. HULL, J. G. JENKINS, et al. 1975. Statistical package for the social sciences. McGraw-Hill, New York. 675 pp.

PFISTER, R. D., and S. F. ARNO. 1980. Classifying forest habitat types based on potential climax vegetation. *For. Sci.* 26:52–70.

PFISTER, R. D., B. L. KOVALCHIK, S. F. ARNO, and R. C. PRESBY. 1977. Forest habitat types of Montana. Gen. Tech. Rep. INT-34. U.S. Dept. Agric., For. Serv., Intermountain For. and Range Exp. Stn., Ogden, Utah. 174 pp.

PHILLIPS, E. L. n.d. Mount Rainier National Park, Washington. *In* Weather Bureau climatography of the United States 20–24. R60-13. U.S. Dept. Commerce, National Weather Service, Washington, D.C. 4 pp.

PLUMMER, F. G. 1900. Mount Rainier Forest Reserve, Washington. Pages 81–143 *in* 21st annual report, 1899–1900: Part 5. Forest reserves. U.S. Dept. Inter., Geological Survey, Washington, D.C.

RICHARDSON, D. 1968. Glacial outburst floods in the Pacific Northwest. U.S. Dept. Inter., Geological Survey Prof. Pap. 387-B. U.S. Govt. Printing Office, Washington, D.C. 20 pp.

SHIMWELL, D. W. 1972. The description and classification of vegetation. Univ. Washington Press, Seattle. 322 pp.

SIGAFOOS, R. S., and E. L. HENDRICKS. 1972. Recent activity of glaciers of Mount Rainier. U.S. Dept. Inter., Geological Survey, Washington, D.C. 20 pp.

SINGER, M., and F. C. UGOLINI. 1984. Genetic history of two well-drained subalpine soils formed on complex parent materials. *Can. J. For. Sci.* 54:475–489.

SOIL SURVEY STAFF. 1975. Soil taxonomy. Agric. Handb. 436. U.S. Department of Agriculture, Washington, D.C. 754 pp.

SWANSTON, D. N., and F. J. SWANSON. 1976. Timber harvesting, mass erosion and steepland forest geomorphology in the Pacific Northwest. Pages 199–221 *in* D. R. Coates, ed., Geomorphology and engineering. Dowden, Hutchinson, and Ross, Stroudsburg, Pennsylvania.

THORNBURGH, D. A. 1969. Dynamics of the true fir-hemlock forests of the west slope of the Washington Cascade Range. Dissertation. Univ. Washington, Seattle. 210 pp.

TOPIK, C., N. M. HALVORSON, and D. G. BROCKWAY. 1985. Interim plant association and management guide Western Hemlock Zone, Gifford Pinchot National Forest. U.S. Dept. Agric., For. Serv., Pac. Northwest Reg., Portland, Oregon. 80 pp.

U.S. DEPARTMENT OF COMMERCE, WEATHER BUREAU. 1965. Climatic summary of the United States—supplement for 1951 through 1960, Washington. *In* Climatography of the United States 86–39. 92 pp.

WARING, R. H., and J. F. FRANKLIN. 1979. Evergreen coniferous forest of the Pacific Northwest. *Science* 204(4400):1380–1386.

ZOBEL, D. B., A. MCKEE, G. M. HAWK, and C. T. DYRNESS. 1976. Relationships of environment to composition, structure, and diversity of forest communities of the central western Cascades of Oregon. *Ecol. Monogr.* 46(2):135–156.

Appendix A.
Keys to Typical Forest Types of Mount Rainier National Park

1. Forests less than 150 years old .... go to Key A
1. Forests over 150 years old 2
2. Forests above 1100 m (3,600 ft) elevation .... go to Key B
2. Forests below 1100 m (3,600 ft) elevation 3
3. Forests of valleys or toeslopes or wet sideslopes and benches ... *Oplopanax horridum* and/or ferns (*Polystichum munitum, Blechnum spicant, Gymnocarpium dryopteris, Athyrium filix-femina*) common .... go to Key C
3. Forests of dry or mesic (but not wet) sideslopes, ridges, or benches. *Oplopanax horridum* absent or rare 4
4. Forests of mesic slopes and benches. Dominant trees are *Pseudotsuga menziesii, Tsuga heterophylla, Abies amabilis, Abies procera*, and sometimes *Chamaecyparis nootkatensis* .... go to Key D
4. Forests of dry slopes and exposures. Dominant trees are *Pseudotsuga menziesii, Tsuga heterophylla, Thuja plicata*, and sometimes *Pinus monticola* .... go to Key E

Key A. Forests Less Than 150 Years Old

1. *Abies lasiocarpa* dominates regeneration and canopy .... *Abies lasiocarpa/Valeriana sitchensis*
1. *Abies lasiocarpa* minor or absent 2
2. *Alnus rubra* dominates or codominates canopy .... *Alnus rubra/Rubus spectabilis*
2. *Alnus rubra* minor or absent 3
3. *Menziesia ferruginea* cover greater than 5 percent, *Abies amabilis* dominates or codominates canopy .... *Abies amabilis/Menziesia ferruginea*

3. *Menziesia ferruginea* cover less than 5 percent, *Pseudotsuga menziesii* usually dominant or codominant in canopy 4
4. *Ceanothus velutinus* present . . . . *Pseudotsuga menziesii/Ceanothus velutinus*
4. *Ceanothus velutinus* absent 5
5. *Xerophyllum tenax* cover less than 5 percent, and *Viola sempervirens* cover more than 1 percent . . . . *Pseudotsuga menziesii/Viola sempervirens*
5. *Xerophyllum tenax* cover more than 5 percent and/or *Viola sempervirens* cover less than 1 percent . . . . *Pseudotsuga menziesii/Xerophyllum tenax*

Key B. High-Elevation Forests, *Tsuga mertensiana* Zone

1. *Oplopanax horridum* more than 2 percent cover . . . . *Abies amabilis/Oplopanax horridum*
1. *Oplopanax horridum* less than 2 percent cover 2
2. *Gaultheria shallon* more than 5 percent cover . . . . *Abies amabilis/Gaultheria shallon*
2. *Gaultheria shallon* less than 5 percent cover 3
3. *Berberis nervosa* more than 3 percent cover . . . . *Abies amabilis/Berberis nervosa*
3. *Berberis nervosa* less than 3 percent cover 4
4. *Abies lasiocarpa* dominates regeneration and canopy, *Valeriana sitchensis* more than 5 percent cover . . . . *Abies lasiocarpa/Valeriana sitchensis*
4. *Abies lasiocarpa* minor or absent, *Valeriana sitchensis* usually less than 5 percent cover 5
5. *Xerophyllum tenax* more than 10 percent cover . . . . *Abies amabilis/Xerophyllum tenax*
5. *Xerophyllum tenax* less than 10 percent cover 6
6. *Chamaecyparis nootkatensis* at least codominant in canopy or regeneration *and* either *Vaccinium ovalifolium* or *Rubus pedatus* cover more than 10 percent . . . . *Chamaecyparis nootkatensis/Vaccinium ovalifolium*
6. *Chamaecyparis nootkatensis* absent or minor *or* both *Vaccinium ovalifolium* and *Rubus pedatus* less than 10 percent cover 7
7. Shrub cover appreciably less than the usually profuse herb cover . . . . *Abies amabilis/Tiarella unifoliata*
7. Shrub cover equal to or greater than herb cover 8
8. *Menziesia ferruginea* cover greater than 5 percent *or Rhododendron albiflorum* cover greater than 5 percent *or Vaccinium alaskaense* cover greater than 5 percent 9
8. *Menziesia ferruginea* or *Rhododendron albiflorum* or *Vaccinium alaskaense* cover less than 5 percent 11

9. *Vaccinium alaskaense* cover greater than 10 percent *or Rhododendron albiflorum* and *Menziesia ferruginea* cover both less than 1 percent .... *Abies amabilis/Vaccinium* .... *alaskaense*, go to key D, step 3
9. *Vaccinium alaskaense* cover less than 10 percent and *Rhododendron albiflorum* or *Menziesia ferruginea* cover greater than 1 percent 10
10. *Rhododendron albiflorum* cover greater than *Menziesia ferruginea* cover................ *Abies amabilis/Rhododendron albiflorum*
10. *Rhododendron albiflorum* cover less than *Menziesia ferruginea* cover.................... *Abies amabilis/Menziesia ferruginea*
11. *Erythronium montanum* cover greater than 10 percent .... *Abies amabilis/Rubus lasiococcus, Erythronium montanum* phase
11. *Erythronium montanum* cover less than 10 percent .... *Abies amabilis/Rubus lasiococcus, Rubus lasiococcus* phase

Key C. Forests of Wet Sites Below 1100 m (3,600 ft) Elevation

1. *Oplopanax horridum* cover greater than 2 percent 2
1. *Oplopanax horridum* cover less than 2 percent............... 3
2. *Abies amabilis* codominant or dominant in canopy or regeneration .... *Abies amabilis/Oplopanax horridum*
2. *Abies amabilis* minor ... *Tsuga heterophylla/Oplopanax horridum*
3. *Abies amabilis* codominant in regeneration or canopy .... *Tsuga heterophylla/Polystichum munitum, Abies amabilis* phase
3. *Abies amabilis* minor ... *Tsuga heterophylla/Polystichum munitum*

Key D. Forests of Mesic Sites Below 1100 m (3,600 ft) Elevation

1. *Abies amabilis* minor in canopy and regeneration, *Achlys triphylla* cover usually greater than 10 percent....................... .... *Tsuga heterophylla/Achlys triphylla*
1. *Abies amabilis* dominant or codominant 2
2. Total cover of shrubs greater than or equal to total cover of herbs .... *Abies amabilis/Vaccinium alaskaense* phases 3
2. Shrub cover less than the rather profuse herb cover .... *Abies amabilis/Tiarella unifoliata*
3. *Chamaecyparis nootkatensis* codominant in canopy and regeneration .... *Chamaecyparis nootkatensis* phase
3. *Chamaecyparis nootkatensis* minor 4
4. *Rubus pedatus* cover greater than 10 percent .... *Rubus pedatus* phase
4. *Rubus pedatus* cover less than 10 percent 5
5. *Berberis nervosa* cover greater than 5 percent .... *Berberis nervosa* phase

5. *Berberis nervosa* cover less than 5 percent .... Typical *Vaccinium alaskaense* phase

Key E. Forests of Dry Sites Below 1100 m (3,600 ft) Elevation

1. *Gaultheria shallon* cover greater than 5 percent 2
1. *Gaultheria shallon* cover less than 5 percent, *Berberis nervosa* cover usually greater than 5 percent .... *Abies amabilis/Berberis nervosa*
2. *Abies amabilis* dominant or codominant in canopy or regeneration, *Chamaecyparis nootkatensis* often present .... *Abies amabilis/Gaultheria shallon*
2. *Abies amabilis* minor, *Chamaecyparis nootkatensis* never present .... *Tsuga heterophylla/Gaultheria shallon*

Appendix B.
Synopses of the Forest Types of Mount Rainier National Park

Tsuga heterophylla/Achlys triphylla Habitat Type

The *Tsuga heterophylla/Achlys triphylla* habitat type is found at low elevations, rarely as high as 1080 m (3,500 ft), primarily on well-drained alluvial flats and lower slopes in the Ohanapecosh and Cowlitz River drainages. Slopes are usually gentle, 0 to 30 percent, although as the elevation increases, this habitat is occasionally found on steeper slopes, up to about 60 percent. Slope aspect tends to be southerly. Dominant canopy species are *Pseudotsuga menziesii*, *Tsuga heterophylla*, and *Thuja plicata*. *Pinus monticola* and *Abies procera* may occur as codominants. Regeneration is largely *Tsuga heterophylla* with some *Thuja plicata*, *Abies amabilis*, and rarely *Abies procera*. The understory is moderately rich in herbs, with *Achlys triphylla*, *Viola sempervirens*, *Cornus canadensis*, *Linnaea borealis*, *Smilacina stellata*, and other herbs totaling an average of about 55 percent cover. *Acer circinatum* is the dominant shrub, averaging 40 percent cover; *Berberis nervosa*, *Vaccinium parvifolium*, *Rubus ursinus*, and other shrubs are common for an average total shrub cover of about 60 percent.

Tsuga heterophylla/Polystichum munitum Habitat Type

The *Tsuga heterophylla/Polystichum munitum* habitat type is found on mesic to moist sites primarily in the western half of Mount Rainier National Park (the Park). Though occurring mostly on well-drained lower slopes and benches, it can be found on slopes up to 70 percent or more with any aspect at elevations less than about 910 m (3,000 ft). Dominant canopy species are *Pseudotsuga menziesii*, *Tsuga hetero-*

phylla, and *Thuja plicata*. *Tsuga heterophylla* dominates regeneration with occasional *Abies amabilis* and *Thuja plicata*. *Polystichum munitum* dominates the herb layer with *Blechnum spicant*, *Tiarella trifoliata*, and *Gymnocarpium dryopteris* as common associates. The herb layer averages about 40 percent cover. *Berberis nervosa* is the most common shrub, often commonly associated with *Vaccinium parvifolium*. *Acer circinatum* and *Taxus brevifolia* are occasionally abundant. Average shrub cover is about 20 percent.

Abies amabilis Phase

The *Abies amabilis* phase occurs in the northwest sector of the Park and is similar to the rest of the *Tsuga heterophylla/Polystichum munitum* habitat type except that *Abies amabilis* is codominant with *Tsuga heterophylla* in regeneration and, to a lesser extent in the canopy. *Blechnum spicant* usually has at least as much cover in the herb layer as *Polystichum munitum*.

Tsuga heterophylla/Oplopanax horridum Habitat Type

The *Tsuga heterophylla/Oplopanax horridum* habitat type occurs at any aspect on moist benches and valley bottoms below 1100 m (3,600 ft) throughout the Park. Slopes are usually gentle, 30 percent or less, but may be as much as 60 percent. The canopy is dominated by *Pseudotsuga menziesii*, *Thuja plicata*, and *Tsuga heterophylla*, all of which may be very large. *Tsuga heterophylla* dominates the regeneration with *Thuja plicata* and *Abies amabilis* common. *Abies grandis* may be locally abundant in the canopy or regeneration. *Oplopanax horridum* dominates the shrub layer with *Acer circinatum* as a common associate. Total shrub cover is usually about 35 percent. The herb layer is rich and luxiurant, averaging over 100 percent cover. Dominant herbs are *Gymnocarpium dryopteris*, *Tiarella trifoliata*, *Athyrium filix-femina*, and *Polystichum munitum*.

Alnus rubra/Rubus spectabilis Community Type

The *Alnus rubra/Rubus spectabilis* community type is early seral, generally less than 150 years old, and is located at low elevations, less than 910 m (3,000 ft), in valley bottoms or on wet side slopes and terraces. *Alnus rubra* and *Tsuga heterophylla* dominate the sparse canopy. *Tsuga heterophylla* is the main generating species with *Abies amabilis* common. The herb layer is rich and profuse, generally totalling over 90 percent cover. *Circaea alpina*, *Athyrium filix-femina*, *Viola glabella*, *Gymnocarpium dryopteris*, and *Tiarella unifoliata* are dominant herbs. *Rubus spectabilis* and *Oplopanax horridum* dominate the shrub layer, which averages over 70 percent cover.

Abies amabilis/Oplopanax horridum Habitat Type

The *Abies amabilis/Oplopanax horridum* habitat type is found on moist lower slopes, benches, and valley bottoms facing any aspect at moderate elevations, 700 to 1210 m (2,300 to 4,000 ft). Slopes are usually gentle, less than 50 percent. The canopy is dominated by *Pseudotsuga menziesii, Tsuga heterophylla*, and *Thuja plicata*, individuals of which may be very large. Regeneration is codominated by *Tsuga heterophylla* and *Abies amabilis* with infrequent *Thuja plicata*. The herb layer is often rich and profuse, usually over 80 percent cover, with *Tiarella unifoliata, Achlys triphylla, Athyrium filix-femina*, and *Adenocaulon bicolor* as dominants. *Oplopanax horridum* and *Vaccinium alaskaense* are the dominants of the shrub layer, which averages less than 40 percent cover.

Slope Phase

The slope phase of this habitat type occurs on moist, steep (over 40 percent) lower slopes to midslopes at up to 1460 m (4,800 ft) in elevation. The canopy dominants are the same as those in the habitat type, but several additional tree species occur: *Picea engelmannii, Abies procera*, and *Tsuga mertensiana*. *Chamaecyparis nootkatensis* is a local codominant in the canopy or regeneration. *Rubus spectabilis* is usually more important than *Vaccinium alaskaense* in the shrub layer. The herb layer is generally more profuse, with an average cover of 90 percent.

Tsuga heterophylla/Gaultheria shallon Habitat Type

This habitat type occurs throughout the Park on dry sites between 610 and 1090 m (2,000 and 3,600 ft). It occurs mostly on moderate to steep south- to west-facing slopes. *Pseudotsuga menziesii, Tsuga heterophylla*, and, to a lesser degree, *Thuja plicata* dominate the canopy. Regeneration is almost exclusively *Tsuga heterophylla* and occasionally *Abies amabilis*. *Linnaea borealis, Achlys triphylla, Xerophyllum tenax*, and *Chimaphila umbellata* are the most important herbs. *Gaultheria shallon* is the dominant shrub, averaging 45 percent cover, with *Berberis nervosa, Vaccinium parvifolium, Vaccinium alaskaense*, and *Acer circinatum* as common associates. Total shrub cover averages about 80 percent and total herb cover 20 percent.

Pseudotsuga menziesii/Ceanothus velutinus Community Type

This early seral community appears in the Ohanapecosh and Cowlitz River drainages on dry sites between 940 and 1240 m (3,100 and 4,100 ft). It occurs on steep upper slopes and midslopes with southerly aspects. Stand ages are usually less than 100 years. *Pseudotsuga menziesii, Abies procera*, and *Pinus monticola* are the dominant canopy and regenerating species. *Acer circinatum, Vaccinium membranaceum*, and *Ceanothus velutinus* are the major shrubs. *Pteridium aquilinum, Fra-*

garia spp., *Achlys triphylla*, and *Rubus lasiococcus* dominate the herbaceous layer. Both the shrub and herb layers are sparse, averaging 55 percent and 35 percent total coverage, respectively.

***Pseudotsuga menziesii/Xerophyllum tenax* Community Type**

This early seral community occurs in scattered locations around the Park. It is found on moderate to low elevations, 1210 to 810 m (4,000 to 2,800 ft), dry benches and southerly facing midslopes to upper slopes. Steepness of slope ranges from nearly flat to 50 percent. *Pseudotsuga menziesii* and *Tsuga heterophylla* dominate the canopy, with *Abies amabilis, Pinus monticola*, and *Abies procera* as common associates. *Tsuga heterophylla* is the major regenerating tree, but several others may be locally important, especially *Pseudotsuga menziesii. Xerophyllum tenax* and *Pteridium aquilinum* are the dominant herbs. *Gaultheria ovatifolia, Vaccinium membranaceum, Vaccinium parvifolium*, and *Pachystima myrsinites* are important shrubs. Both shrubs and herbs average 50 percent total cover.

***Pseudotsuga menziesii/Viola sempervirens* Community Type**

This widespread early seral community occurs mostly in the southern half of the Park. It usually appears on southerly facing midslopes to upper slopes and ridges, or rarely on benches or in valley bottoms. Slopes range from nearly flat to 70 percent and from about 670 to 1300 m (2,200 to 4,300 ft) in elevation. *Pseudotsuga menziesii* and, to a lesser degree, *Tsuga heterophylla* dominate the canopy. While *Tsuga heterophylla* is the most abundant regenerating species, many other species may occur and be locally important (including *Pseudotsuga menziesii, Abies amabilis, Pinus monticola, Abies grandis*, and others). *Pteridium aquilinum, Viola sempervirens, Linnaea borealis, Achlys triphylla*, and *Chimaphila umbellata* are the most important herbs. *Acer circinatum, Berberis nervosa*, and *Gaultheria ovatifolia* are the dominant shrubs. Total shrub cover is usually about 35 percent and total herb cover 55 percent.

***Abies amabilis/Gaultheria shallon* Habitat Type**

This habitat type occurs on steep (20 to 80 percent), well-drained, southerly facing slopes in the west and southwest sections of the Park. Elevations are moderately high, usually between 910 and 1300 m (3,000 and 4,300 ft). *Tsuga heterophylla* and *Pseudotsuga menziesii* dominate the canopy. *Abies amabilis* and *Tsuga heterophylla* are the major regenerating species. *Thuja plicata* seedlings occur less frequently. *Xerophyllum tenax* is the most important herb, usually with *Linnaea borealis, Chimaphila umbellata*, and *Cornus canadensis. Gaultheria shallon, Berberis nervosa, Vaccinium parvifolium, Vac-*

cinium alaskaense, and *Vaccinium membranaceum* are the major shrub species. Average total shrub cover is 60 percent and average total herb cover 20 percent.

***Abies amabilis/Berberis nervosa* Habitat Type**

This widespread habitat type is found on well-drained slopes at elevations of from 770 to 1420 m (2,500 to 4,700 ft). Slope angle is usually greater than 25 percent. Aspects tend to be southerly although the type does occur on northerly facing slopes at low elevations. Sites occupied by this type are characteristically mesic to dry and warm. *Abies amabilis*, *Tsuga heterophylla*, and *Pseudotsuga menziesii* dominate the canopy, with *Thuja plicata* and *Abies procera* as common associates. *Abies amabilis* is the dominant regenerating species, with *Tsuga heterophylla* often abundant. *Berberis nervosa* is the most consistently present shrub. *Acer circinatum* is locally important. *Chimaphila umbellata*, *Linnaea borealis*, and *Achlys triphylla* are the dominant herbs. Average shrub cover is 20 percent and average herb cover 20 percent.

***Abies amabilis/Xerophyllum tenax* Habitat Type**

This habitat occurs on midslopes to upper slopes and ridges generally above 1000 m (3,300 ft). Slopes may be flat to 90 percent or more. Aspects likewise vary from 0° to 360°. Sites are typically well drained and often rocky or thin soiled. *Abies amabilis* is the dominant canopy tree, but several other species may be common: *Tsuga heterophylla*, *Abies procera*, *Pseudotsuga menziesii*, *Abies lasiocarpa*, *Tsuga mertensiana*, and *Chamaecyparis nootkatensis*. *Abies amabilis* is by far the leading regenerating species, although *Tsuga heterophylla* seedlings may be common. *Vaccinium membranaceum* is the most important shrub and is commonly associated with several others, especially *Menziesia ferruginea*, *Vaccinium alaskaense*, and *Vaccinium ovalifolium*. *Xerophyllum tenax* is the dominant herb and is usually associated with *Rubus lasiococcus*, *Pyrola secunda*, and *Linnaea borealis*.

***Abies amabilis/Vaccinium alaskaense* Habitat Type**

The *Abies amabilis/Vaccinium alaskaense* habitat is the most common in the Park. It occurs throughout the Park on mesic sites between 640 and 1370 m (2,100 and 4,500 ft). Most of this habitat occurs on lower slopes, benches, and in valley bottoms where slopes are between 0 and 90 percent. It also appears on upper slopes in the northwest sector of the Park. Canopy dominants are *Tsuga heterophylla*, *Pseudotsuga menziesii*, and *Abies amabilis*. *Thuja plicata*, *Chamaecyparis nootkatensis*, *Abies procera*, and *Tsuga mertensiana* may be locally important. Regeneration is mostly *Abies amabilis* and, to a lesser ex-

tent, *Tsuga heterophylla*. The other tree species, especially *Chamaecyparis nootkatensis*, may be locally important in the regeneration. The habitat is predominantly shrubby. Several shrub species are common, including *Vaccinium alaskaense, Vaccinium parvifolium, Vaccinium ovalifolium*, and *Vaccinium membranaceum*. *Linnaea borealis, Rubus pedatus, Clintonia uniflora*, and *Blechnum spicant* are the most abundant herbs. Total shrub cover averages 75 percent and total herb cover 20 percent.

Berberis nervosa Phase

This phase occurs at the lower end of the elevation spectrum, from 580 to 1200 m (1,900 to 4,000 ft). Aspects tend to be southerly and westerly. *Pseudotsuga menziesii* is the major dominant in the canopy followed by *Tsuga heterophylla*. *Linnaea borealis* and *Cornus canadensis* dominate the herb layer. *Berberis nervosa* is a dominant shrub along with several *Vaccinium* species.

Rubus pedatus Phase

This phase appears mainly in the northwest sector of the Park. *Tsuga heterophylla, Pseudotsuga menziesii, Abies amabilis*, and, locally, *Chamaecyparis nootkatensis* dominate the canopy. *Rubus pedatus* is the dominant herb, with *Clintonia uniflora* as a common associate. *Vaccinium parvifolium* and *Berberis nervosa* are only minor constituents of the shrub layer.

Chamaecyparis nootkatensis Phase

This phase is scattered around the Park at 901 to 1270 m (3,000 to 4,200 ft) on moderately steep (20- to 65-percent), lower slopes. Its distinctive features are a very low total herb cover, about 5 percent, and the importance of *Chamaecyparis nootkatensis* as a codominant in both the canopy and regeneration.

Abies amabilis/Tiarella unifoliata Habitat Type

The *Abies amabilis/Tiarella unifoliata* habitat type occurs on nearly all forested moist to mesic landforms and facing any aspect between 818 and 1390 m (2,700 and 4,600 ft) elevation. *Abies procera* is a frequent canopy dominant along with *Tsuga heterophylla, Abies amabilis, Chamaecyparis nootkatensis*, and *Pseudotsuga menziesii*. Regeneration is mainly *Abies amabilis* associated with *Tsuga heterophylla*. The understory is usually strongly herbaceous. Average herb cover is 75 percent. Shrubs are minor, averaging 10 percent cover. *Tiarella unifoliata, Achlys triphylla, Rubus lasiococcus*, and *Streptopus roseus* dominate the herb layer. *Vaccinium ovalifolium* and *Vaccinium membranaceum* are the most common shrubs.

Abies amabilis/Rubus lasiococcus Habitat Type

Rubus lasiococcus Phase

This phase of the *Abies amabilis/Rubus lasiococcus* habitat type is found at elevations above 1200 m (4,000 ft) on a variety of landforms. Slopes are generally steep. Slope aspect is usually north or northeast. This type frequently is directly below the subalpine meadowland or the *Abies lasiocarpa/Valeriana sitchensis* community. Although several conifers occur in the canopy and as regeneration, *Abies amabilis* is the most important. *Chamaecyparis nootkatensis, Tsuga mertensiana, Tsuga heterophylla*, and *Abies lasiocarpa* are frequently present. *Vaccinium membranaceum* is the dominant shrub. Other common shrubs are several species of *Vaccinium* and *Rhododendron albiflorum*. *Rubus lasiococcus* is a common, abundant herb. Frequent associates are *Valeriana sitchensis, Arnica latifolia, Pyrola secunda*, and *Rubus pedatus*. This type is distinctly shrubby with an average shrub cover of 30 percent and an average herb cover of 20 percent.

Abies amabilis/Rubus lasiococcus Habitat Type

Erythronium montanum Phase

This phase of the *Abies amabilis/Rubus lasiococcus* habitat type occurs at high elevations, above 1300 m (4,300 ft), on midslopes to upper slopes, benches, and ridges that receive a heavy, late-melting snowpack. Slopes range from flat to 70 percent or more and can face any aspect. *Abies amabilis* is the dominant tree species from the seedling layer to the canopy. *Chamaecyparis nootkatensis* and *Tsuga mertensiana* are common components of both the canopy and regeneration. *Vaccinium membranaceum, Rhododendron albiflorum*, and other species of *Vaccinium* are the most important shrubs. *Erythronium montanum, Rubus lasiococcus*, and *Rubus pedatus* are the dominant shrubs. Total shrub cover averages 20 percent and total herb cover 40 percent.

Abies lasiocarpa/Valeriana sitchensis Community Type

This widespread community commonly occurs at and just below the ecotone between subalpine meadow and closed forest. It usually occurs above 1400 m (4,600 ft) on sites with almost any combination of slope and aspect. The canopy is dominated by *Abies lasiocarpa*. *Abies amabilis* may be common. Several other tree species may occur. Regeneration is commonly sparse and mostly *Abies lasiocarpa* and *Abies amabilis*. This community may be successional to various *Abies amabilis* habitats over a very long time. The dominant shrub is *Vaccinium membranaceum* with *Vaccinium scoparium* and several shrubs common. Many herbs of the subalpine meadows occur in combination with some more characteristic of the deep forest. Most common

are *Valeriana sitchensis*, *Rubus lasiococcus*, *Arnica latifolia*, and *Luzula* spp. *Pedicularis rainierensis* occurs in this type at some locations.

***Abies amabilis/Menziesia ferruginea* Habitat Type**

This habitat type usually occurs on steep sites at moderate to high elevations, 1000 to 1400 m (3,300 to 4,600 ft), especially on northerly facing upper slopes. Several tree species are common. *Abies amabilis* dominates both canopy and regeneration. *Tsuga heterophylla*, *Chamaecyparis nootkatensis*, and *Tsuga mertensiana* are frequent associates. Large *Pseudotsuga menziesii* occasionally appear. *Menziesia ferruginea* is the dominant shrub and is commonly associated with *Vaccinium* spp. and *Rhododendron albiflorum*. The principal herbaceous species are *Rubus pedatus*, *Rubus lasiococcus*, *Xerophyllum tenax*, and *Clintonia uniflora*. This type is conspicuously shrubby with an average shrub cover of 45 percent and an average herb cover of 20 percent.

***Chamaecyparis nootkatensis/Vaccinium ovalifolium* Habitat Type**

The *Chamaecyparis nootkatensis/Vaccinium ovalifolium* habitat type occurs mostly on northerly facing moist slopes and benches between 1200 and 1370 m (4,000 and 4,500 ft) in elevation. Slopes are generally moderately steep, 10 to 60 percent. *Tsuga mertensiana*, *Abies amabilis*, and *Chamaecyparis nootkatensis* dominate the canopy. *Abies amabilis*, *Chamaecyparis nootkatensis*, and *Tsuga heterophylla* dominate regeneration with only occasional *Tsuga mertensiana*. The herb layer is moderately rich and is dominated by *Rubus pedatus*, *Tiarella unifoliata*, and *Rubus lasiococcus*. *Erythronium montanum* may be locally abundant. Shrubs are mostly *Vaccinium ovalifolium*, *Menziesia ferruginea*, and *Vaccinium membranaceum*. Average herb cover is 60 percent and average shrub cover 35 percent.

***Abies amabilis/Rhododendron albiflorum* Habitat Type**

This habitat type occurs at moderate to high elevations, 1200 to 1750 m (4,000 to 5,800 ft), on cold, wet sites. Slopes are generally moderate to steep and northerly facing. Landform varies from lower slopes and benches to ridges. Several tree species are common in the canopy and regeneration. *Abies amabilis* is the most important; *Tsuga mertensiana*, *Chamaecyparis nootkatensis*, and *Tsuga heterophylla* are common associates. Large *Pseudotsuga menziesii* may occur. This type is very shrubby with an average shrub cover of 70 percent. *Rhododendron albiflorum*, *Menziesia ferruginea*, and *Vaccinium* spp. are the dominant shrubs. Herbaceous cover is usually low and averages 30 percent. *Erythronium montanum*, *Rubus pedatus*, and *Rubus lasiococcus* are the most important herbs.

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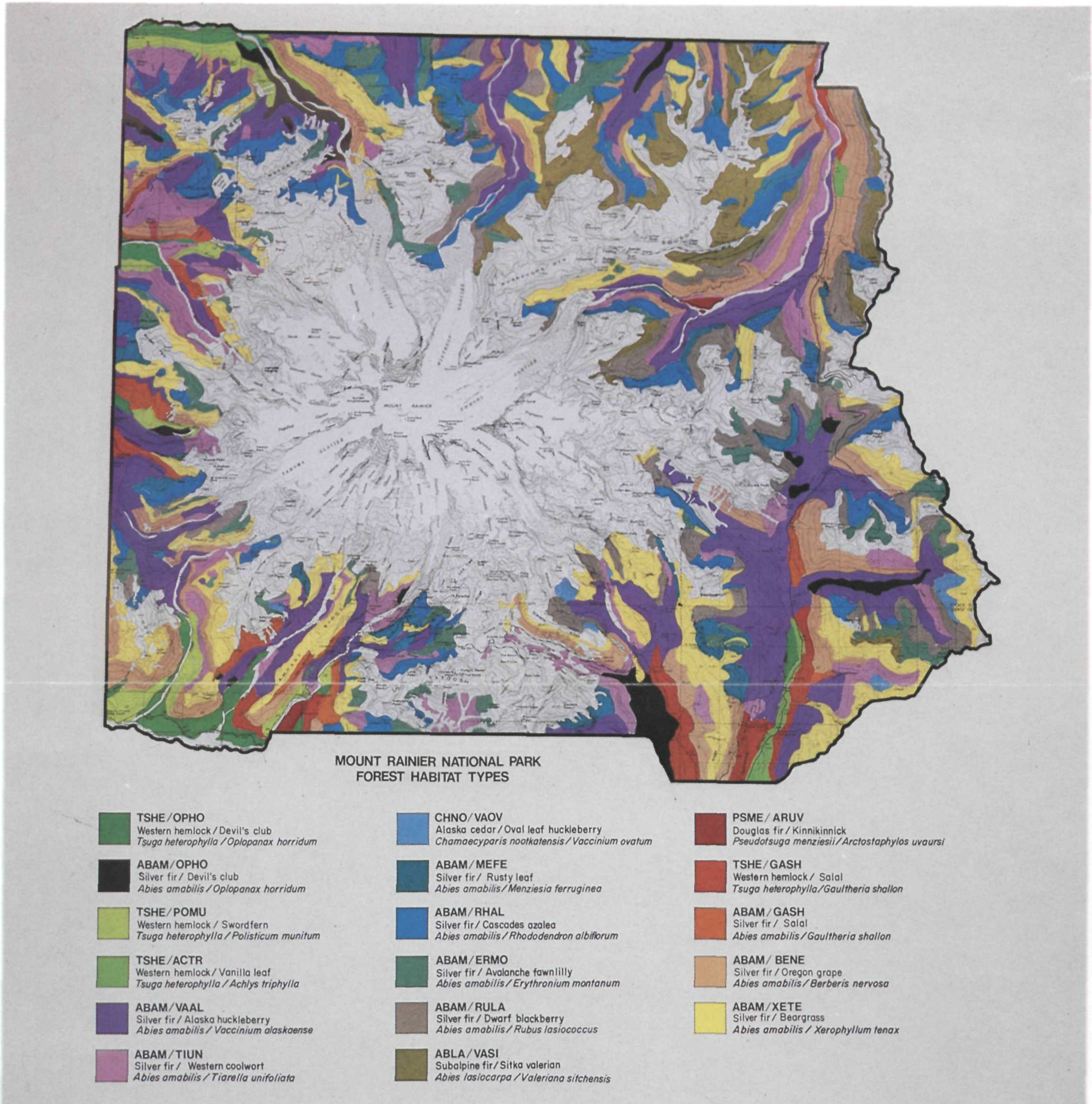

Plate 1. Map showing distribution of habitat types in Mount Rainier National Park.

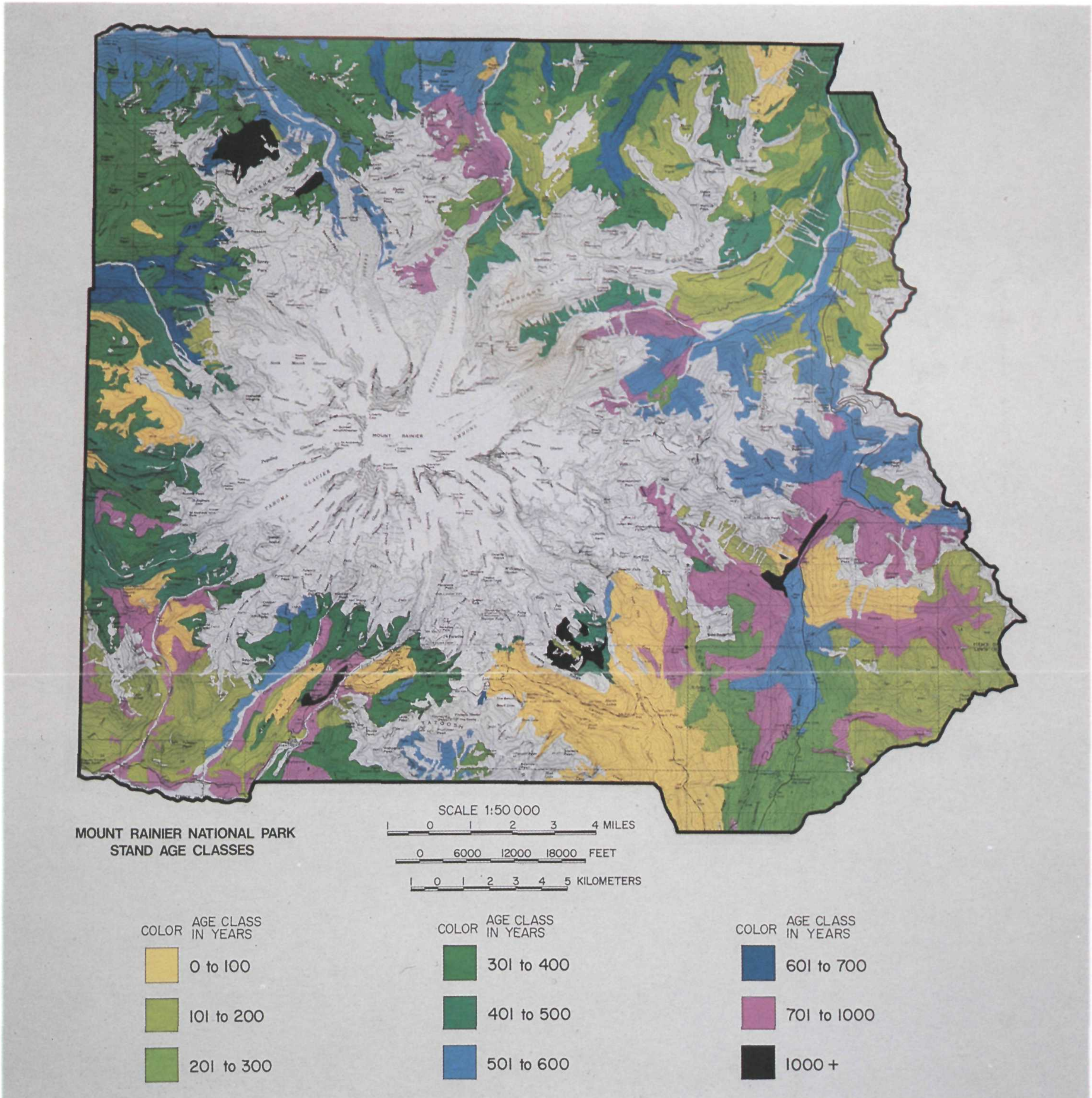

Plate 2. Map showing distribution of forest age classes in Mount Rainier National Park.

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